Table of Contents

Undergraduate

To Mines students:

This Catalog is for your use as a source of continuing reference. Please save it.

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Registrar: Paul Myskiw, Registrar, registrar@mines.edu
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Welcome

The Academic Environment

We strive to fulfill this educational mission through our undergraduate curriculum and in an environment of commitment and partnership among students and faculty. The commitment is directed at learning, academic success and professional growth, it is achieved through persistent intellectual study and discourse, and it is enabled by professional courtesy, responsibility and conduct. The partnership invokes expectations for both students and faculty. Students should expect access to high quality faculty and to appropriate academic guidance and counseling; they should expect access to a high quality curriculum and instructional programs; they should expect to graduate within four years if they follow the prescribed programs successfully; and they should expect to be respected as individuals in all facets of campus activity and should expect responsive and tactful interaction in their learning endeavors. Faculty should expect participation and dedication from students, including attendance, attentiveness, punctuality and demonstrable contribution of effort in the learning process; and they should expect respectful interaction in a spirit of free inquiry and orderly discipline. We believe that these commitments and expectations establish the academic culture upon which all learning is founded.

Mines offers the Bachelor of Science degree in Applied Mathematics and Statistics, Biochemistry, Business Engineering & Management Science, Ceramic Engineering, Chemical Engineering, Chemistry, Civil Engineering, Computer Science, Construction Engineering, Design Engineering, Economics, Electrical Engineering, Engineering Physics, Environmental Engineering, Geological Engineering, Geophysical Engineering, Mechanical Engineering, Metallurgical and Materials Engineering, Mining Engineering, Petroleum Engineering and Quantitative Biosciences & Engineering.

An institutional goal for all of these programs is articulated in the *Profile of the Colorado School of Mines Graduate:*

- All Mines graduates must have depth in an area of specialization, enhanced by hands-on experiential learning and breadth in allied fields. They must have the knowledge and skills to be able to recognize, define and solve problems by applying sound scientific and engineering principles. These attributes uniquely distinguish our graduates to better function in increasingly competitive and diverse technical professional environments.
- Graduates must have the skills to communicate information, concepts and ideas effectively orally, in writing, and graphically. They must be skilled in the retrieval, interpretation and development of technical information by various means, including the use of computer-aided techniques.
- Graduates should have the flexibility to adjust to the ever-changing professional environment and appreciate diverse approaches to understanding and solving society's problems. They should have the creativity, resourcefulness, receptivity and breadth of interests to think critically about a wide range of cross-disciplinary issues. They should be prepared to assume leadership roles and possess the skills and attitudes which promote teamwork and cooperation and to continue their own growth through lifelong learning.
- Graduates should be capable of working effectively in an international environment and be able to succeed in an increasingly interdependent world where borders between cultures and economies are becoming less distinct. They should appreciate the traditions and languages of other cultures, and value diversity in their own society.
- Graduates should exhibit ethical behavior and integrity. They should also demonstrate perseverance and have pride in accomplishment. They should assume a responsibility to enhance their professions through service and leadership and should be responsible citizens who serve society, particularly through stewardship of the environment.

History of Colorado School of Mines

In 1865, only six years after gold and silver were discovered in the Colorado Territory, the fledgling mining industry was in trouble. The nuggets had been picked out of streams and the rich veins had been worked, and new methods of exploration, mining, and recovery were needed.

Early pioneers like W.A.H. Loveland, E.L. Berthoud, Arthur Lakes, George West and Episcopal Bishop George M. Randall proposed a school of mines. In 1874, the Territorial Legislature appropriated $5,000 and commissioned Loveland and a Board of Trustees to found the Territorial School of Mines in or near Golden. Governor Routt signed the bill on February 9, 1874, and when Colorado became a state in 1876, the Colorado School of Mines was constitutionally established. The first diploma was awarded in 1883.

As Mines grew, its mission expanded from the rather narrow initial focus on nonfuel minerals to programs in petroleum production and refining as well. Recently it has added programs in materials science and engineering, energy and environmental engineering, and a broad range of other engineering and applied science disciplines. Mines sees its mission as education and research in engineering and applied science with a special focus on the earth science disciplines in the context of responsible stewardship of the earth and its resources.

Mines long has had an international reputation. Students have come from nearly every nation, and alumni can be found in every corner of the globe.

Colorado School of Mines is a public research university devoted to engineering and applied science. It has the highest admission standards of any public university in Colorado and among the highest of any public university in the United States.

Unique Programs

Colorado School of Mines is an institution of engineering and applied science with a special focus in Earth, Energy, Environment and Materials. As such, it has unique programs in many fields. This is the only institution in the world, for example, that offers doctoral programs in all five of the major earth science disciplines: Geology and Geological Engineering, Geophysics, Geochemistry, Mining Engineering and Petroleum Engineering. It has one of the few Metallurgical and Materials Engineering programs in the country that still focuses on the complete materials cycle from mineral processing to finished advanced materials.

In addition to these traditional programs which define the institutional focus, the school is pioneering programs in interdisciplinary areas. One of the most successful of these is in the College of Engineering and Computational Sciences, which currently claims more than one-third of the undergraduate majors. This program combines civil, electrical, environmental and mechanical engineering in a nontraditional curriculum that is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012 – telephone (410) 347-7700.

While many of the programs at Mines are firmly grounded in tradition, they are all experiencing continual evolution and innovation. Recent successes in integrating aspects of the curriculum have spurred similar activity in other areas such as the geosciences. There, through the medium of computer visualization, geophysicists and geologists are in the process of creating a new emerging discipline. A similar development is occurring in geoengineering through the integration of aspects of civil engineering, geology and mining. Mines has played a leadership role in this kind of innovation over the last decade. Many degree programs offer Mines undergraduate students the opportunity to begin work on a graduate certificate, professional master’s degree, or master’s degree while completing the requirements for their bachelor’s degree. These combined bachelor's-master's programs have been created by Mines faculty in those situations where they have deemed it academically advantageous to treat BS and MS degree programs as a continuous and integrated process. These are accelerated programs that can be valuable in fields of engineering and applied science where advanced education in technology and/or management provides the opportunity to be on a fast track for advancement to leadership positions. These programs also can be valuable for students who want to get a head start on graduate education.

Location

Golden, Colorado has been the home for Mines since its inception. Located 20 minutes west of Denver, this community of 20,000 is located in the foothills of the Rockies. Skiing is an hour away to the west. Golden is a unique community that serves as home to Mines, the Coors Brewing Company, the National Renewable Energy Laboratory, a major U.S. Geological Survey facility that also contains the National Earthquake Center, and the seat of Jefferson County. Golden once served as the territorial capital of Colorado.

Accreditation

Mines is accredited through the doctoral degree by the Higher Learning Commission (HLC) of the North Central Association, 230 South LaSalle Street, Suite 7-500, Chicago, Illinois 60604-1413 – telephone (312) 263-0456. Please look at the individual department pages to learn more about the accreditation of engineering programs. The American Chemical Society has approved the degree program in the Department of Chemistry and Geochemistry.

Administration

General management of the school is vested by State statute in a Board of Trustees, consisting of seven members appointed by the governor. A nonvoting student member is elected annually by the student body and a nonvoting faculty member is elected to serve a two-year term by the academic faculty. Financial support comes from student tuition and fees and from the state through annual appropriations. These funds are augmented by government and privately sponsored research, private gift support from alumni, corporations, foundations and other friends.

Colorado School of Mines Non-Discrimination Statement

In compliance with federal law, including the provisions of Titles VI and VII of the Civil Rights Act of 1964, Title IX of the Education Amendment of 1972, Sections 503 and 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act (ADA) of 1990, the ADA Amendments Act of 2008, Executive Order 11246, the Uniformed Services Employment and Reemployment Rights Act, as amended, the Genetic Information Nondiscrimination Act of 2008, and Board of Trustees Policy 10.6, the Colorado School of Mines does not discriminate against individuals on the basis of age, sex, sexual orientation, gender identity, gender expression, race, religion, ethnicity, national origin, disability, military service, or genetic information in its administration of educational policies, programs, or activities; admissions policies; scholarship and loan programs; athletic or other school-administered programs; or employment.

Inquiries, concerns, or complaints should be directed by subject content as follows:

The EO, ADA Coordinator, and Section 504 Coordinator for employment:
Craig Hess, Director of Employee Relations
Human Resources Office
1500 Illinois Street
Golden, Colorado 80401
303-273-3390

The ADA Coordinator and the Section 504 Coordinator for students and academic educational programs:
Marla Draper, Director of Disability Support Services
1225 17th Street
Golden, Colorado 80401
303-273-3297
disabilitysupport@mines.edu

Title IX Complaints and Student Discrimination Complaints:
Carole Goddard, Title IX Coordinator
Golden, Colorado 80401
303-273-3206
titleix@mines.edu (kschmalz@mines.edu)

The ADA Facilities Access Coordinator is:
Gary Bowersock, Director of Facilities Management
1318 Maple Street
Golden, Colorado 80401

303.273.3330

Student Life at Mines

Facilities

Student Center

The Ben H. Parker Student Center contains the offices for the Vice President of Student Life, Dean of Students, Student Activities, Involvement, and Leadership (SAIL), Student Government (USG), Financial Aid, Bursar and Cashier, New Student and Transition Services (NeST), Career Center, Registrar, Campus Events, Blaster Card Office and student organizations. The Student Center also contains the Periodic Table food court, bookstore, student lounges, meeting rooms, and banquet facilities.

Student Recreation Center

Completed in May 2007, the 108,000 square-foot Student Recreation Center, located at the corner of 16th and Maple Streets in the heart of campus, provides a wide array of facilities and programs designed to meet student's recreational and leisure needs while providing for a healthy lifestyle. The Center contains a state-of-the-art climbing wall, an eight-lane, 25-meter swimming and diving pool, a cardiovascular and weight room, two multi-purpose rooms designed and equipped for aerobics, dance, martial arts programs and other similar activities, a competition gymnasium containing three full-size basketball courts as well as seating for 2500 people, a separate recreation gymnasium designed specifically for a wide variety of recreational programs, extensive locker room and shower facilities, and a large lounge intended for relaxing, playing games or watching television. In addition to housing the Outdoor Recreation Program as well as the Intramural and Club Sports Programs, the Center serves as the competition venue for the Intercollegiate Men and Women's Basketball Programs, the Intercollegiate Volleyball Program and the Men and Women's Intercollegiate Swimming and Diving Program.

W. Lloyd Wright Student Wellness Center

The W. Lloyd Wright Student Wellness Center, 1770 Elm Street, houses several health and wellness programs for Mines students: the Coulter Student Health Center, the Counseling Center, the Dental Clinic, the Student Health Insurance Plan (SHIP), and Student Wellness Promotion & Education. The Wellness Center is open from 8:00 a.m. to 5:00 p.m., Monday through Friday, during the fall and spring semesters. Check the website for summer and holiday hours. The Wellness Center follows weather delays and closure schedules set for the campus.

Coulter Student Health Center: The Coulter Student Health Center (phone 303-273-3381, fax 303-273-3623) is located on the first floor of the W. Lloyd Wright Student Wellness Center. Services are provided to all students who have paid the student health services fee.* Nurse practitioners and registered nurses provide services by appointment Monday through Friday 8:00 a.m. to 12:00 p.m. and 1:00 p.m. to 4:45 p.m. A physician has office hours on campus during the fall and spring semesters. The Health Center offers primary care health services. For X-rays, specialists or hospital care, students are referred to appropriate providers in the community. More information is available at https://www.mines.edu/student-health/.

Immunization Requirement: All incoming students are required to **submit documented proof of specific vaccinations** or laboratory evidence of immunity. These requirements are submitted through the Health Portal which can be found at my.mines.edu. Detailed information on Health Center requirements is available at https://www.mines.edu/student-health/student-health-center/forms/.

- **Measles, Mumps, and Rubella (MMR) Vaccine**: Colorado law requires every student to submit proof of two (2) valid vaccinations for measles, mumps, and rubella (MMR) given no earlier than four days before the student's first birthday. There must be at least twenty-eight (28) calendar days between the two vaccinations.
- **Meningococcal ACWY Vaccine**: Colorado law requires all students living on campus in student housing to either submit proof of a Meningitis ACWY vaccine given within the last five years, or to sign the Meningococcal waiver form. If the five-year period will expire while the student is living on campus, we recommend receiving another Meningococcal ACWY vaccine. Students will have a hold placed on their account five years after the date of the most recent Meningitis ACWY vaccine if they are still living on campus. Currently, Meningitis ACWY is required, Meningitis B is recommended.
- **Tuberculosis:** Completion of the Tuberculosis (TB) Screening questionnaire is required. This form is located in the Health Portal under the Forms tab. In some cases, TB testing may also be indicated.

Counseling Center: Located on the second floor of the W. Lloyd Wright Student Wellness Center (phone 303-273-3377). The Mines Counseling Center is staffed by licensed and experienced mental health professionals, skilled in handling a variety of presenting concerns. Services are designed to assist students in resolving issues that interfere with their ability to successfully navigate the Mines journey. Services are confidential, voluntary, and covered by the student health services fee.* The Counseling Center utilizes a Stepped Care model, which allows students to create a wellness plan that connects them to services that best meet their unique needs. Available service options include initial counselor consultations, skills-based workshops, brief therapy interventions, support groups, drop-in office hours, and care coordination to connect students with community providers for more intensive treatment. Visit our website to learn more about updated virtual and in-person service offerings and resources: https://www.mines.edu/counseling-center/.

Dental Clinic: The Dental Clinic is located on the second floor of the W. Lloyd Wright Wellness Center (phone 303-273-3377). Services include comprehensive exams, cleanings, fillings, x-rays, as well as emergency services. Students who have paid the student health services fee* are eligible for these services. Dental care is on a fee-for-service basis at a fraction of the cost of other dental offices. For the fee schedule, please refer to our Dental Clinic website. The Dental Clinic accepts cash or checks, as well as credit/debit cards. Clinic hours are on Tuesdays, Wednesdays, and Fridays during the academic year with limited hours during the summer. Services are by appointment only and can be made via https://www.mines.edu/student-health/student-health-center/dental-clinic/ using the *Request Appointment* tool or by calling the Dental Clinic at 303-273-3377.

Student Health Insurance Plan (SHIP): *Having adequate health insurance is a condition of enrollment at Colorado School of Mines. All students are charged for the Student Health Insurance Plan (SHIP) and those students with approved waivers will see the waiver credit.* The SHIP office is located on the second floor of the W. Lloyd Wright

Student Wellness Center. Enrollment confirmation or waiver of the Mines Student Health Insurance Plan is done online. The deadline to submit a waiver is Census Day. More information can be found at https://www.mines.edu/student-health/student-insurance/ or by calling the office at 303-273-3388.

> ***Student Health Insurance Plan--Adequate Health Insurance Requirement****: All degree seeking U.S. citizen and permanent resident students, and all international students regardless of degree status, are required to have health insurance. Students are automatically enrolled in the Student Health Insurance Plan and may waive coverage if they have coverage under a personal or employer plan that meets minimum requirements. International students must purchase the SHIP, unless they meet specific requirements. Information about the Mines Student Health Insurance Plan, as well as the criteria for waiving, is available online at* https://www.mines.edu/student-health/student-insurance/ *or by calling 303.273.3388.*

***Fees:** Students are charged a mandatory health services fee each semester which allows them access to services at the Health Center and Dental Clinic.*

Services

Academic Advising

Center for Academic Services and Advising (CASA)

Academic Advising: All students are advised by Academic Advising Coordinators in CASA throughout their undergraduate studies at Mines. First-year and new transfer students are assigned to a CASA first-year advisor based on their last name as they complete core course requirements and explore majors at Mines. Students can begin their Mines coursework undecided or with an intended major, and students are encouraged to explore all of the majors Mines has to offer before deciding which one or more to pursue. Once a student confirms their major, either at the end of their first year or the beginning of their second year, they will transition from their first-year advisor to their CASA major advisor and a faculty mentor within their academic department. Academic advising occurs through individual, scheduled, walk-in, and group advising sessions via remote or in person sessions, as needed. #Students are encouraged to work not only with their academic advisor but also peer advisors, student leaders who provide peer advising to students about registration, course enrollment, majors, minors, and more.

Academic Support Services: CASA offers a wide variety of support services designed to assist students throughout their undergraduate degree. Examples include pre-finals workshops, major exploration events, and the specific support services listed below.

Tutoring: Tutoring services are offered for all core curriculum courses and many major courses by peers. Tutoring is offered Sunday through Thursday in CASA (Aspen Hall) the Library, and via Zoom.

Core Review Sessions: Core Review Sessions are group review sessions held by a peer facilitator before common core course exams. Peer facilitators also host regular office hours for more individualized assistance.

Academic Coaching: Students can work with CASA advisors to develop the skills and technique of studying well in college, such as test-prep and cognitive learning development, in a one-on-one setting.

Faculty in CASA: Faculty from various departments host their regular office hours in CASA. Students are encouraged to utilize these professors for assistance with material and/or questions on course planning.

Visit casa.mines.edu for more information.

Support Services

Career Center

The Mines Career Center assists students in developing, evaluating, and/or implementing career, education, and employment decisions and plans. Career and professional development is integral to the success of Mines graduates and to the mission of Mines.

Students and recent graduates who develop, utilize and apply the services offered by the Mines Career Center will be educated, coached and empowered to conduct a strategic, personalized career exploration and ethical job search that highlights the passions, skills and strengths of each individual. In addition, students are offered opportunities to engage with companies and organizations in a variety of forums to enhance their professional knowledge and diversity of career prospects.

Services are provided to all students and recent graduates, up to 24 months after graduation. Students must adhere to the ethical and professional business and job searching practices as stated in the Career Center Student Policy, which can be found on the student's homepage of DiggerNet. In order to accomplish our mission, we provide a comprehensive array of career services:

Career Advising and Professional Development

- “Tools for Engineering Your Career: The Mines Strategy" a practical career manual with interview strategies, resume and cover letter examples, career exploration ideas, and job search tips.
- Online resources for exploring careers and employers at https://www.mines.edu/careers/.
- Individual job search advice, resume and cover letter critiques.
- Practice interviews.
- Salary and contract negotiation and networking skills.
- Career and Professional Development Workshops - including, career readiness competencies, successful company research, interviewing, resumes, professional branding, and networking skills.

Job Resources and Events

- Career Days (fall and spring).
- Online job search system: DiggerNet.
- Online and in-person job search assistance for internships, co-ops, and full-time entry-level job postings.
- Virtual Career Fairs and special recruiting events.
- On-campus interviewing – industry and government representatives visit the campus to interview students.
- General employment and on-campus jobs board.

Disability Support Services

Disability Support Services (DSS) works collaboratively with students, faculty, and staff to minimize barriers and support an accessible campus community. When barriers to access occur, Disability Support Services works one-on-one with students to determine accommodations and facilitate access to programs and services. For more information or to request disability accommodations, please visit https://disabilities.mines.edu/. DSS is located at 1225 17th Street.

The Mines Testing Center (MTC) serves to support and proctor exams for students with approved testing accommodations. The MTC is located in the Green Center, Room 240. For more information, please visit: https://www.mines.edu/disability-support-services/mtc/.

PASCAL

The Professional and Scholar Communities Applied Learning (PASCAL) Center works to develop, advance and steward scholarship communities and professional development at Mines. PASCAL directly manages scholarship communities, promotes and programs professional development opportunities with campus partners, and meaningfully engages with alumni and donors. Our center's efforts advance Mines@150 aspirations to actively support community, scholarship, professional development, engagement and applied learning for all students at Mines. Learn more about https://www.mines.edu/pascal/.

MEP

The Colorado School of Mines Multicultural Engineering Program (MEP) was established in 1989. Over the years, MEP has played a significant role in promoting the ongoing commitment Mines has to create a more diverse and inclusive learning community. We work to enroll, retain, and graduate underrepresented students, and continue to build a community of support through our many partnerships and advocacies. MEP offers the following opportunities and programs:

- Academic Support – MEP/ CASA Tutors
- Undergraduate Research Opportunities
- Leadership Opportunities within Professional Societies
- Professional Development events
- Scholarship search assistance
- Support for First Generation students
- Networking with industry and community representatives for internship and employment opportunities
- Graduate School pathway partnerships
- Annual MEP Banquet honoring graduating undergraduate and graduate students

More information at: https://mep.mines.edu/.

Identification Cards (Blaster Card Office)

All new students must have a Blaster Card made as soon as possible after they enroll. The Blaster Card office also issues RTD College Passes, which allow students to ride RTD buses and light rail free of charge. More information can be found at https://www.mines.edu/student-life/blastercard/.

The Blaster Card can be used for student meal plans, to check material out of the Arthur Lakes Library, to access certain electronic doors, and may be required to attend various campus activities.

Motor Vehicles Parking

All motor vehicles on campus must be registered with the campus Parking Services Division of Facilities Management, 1318 Maple Street, and must display a CSM parking permit. Vehicles must be registered at the beginning of each semester or upon bringing your vehicle on campus, and updated whenever you change your address.

Public Safety

The Colorado School of Mines Department of Public Safety is a full service, community oriented law enforcement agency, providing 24/7 service to the campus. It is the mission of the Colorado School of Mines Police Department to make the Mines campus the safest campus in Colorado.

The department is responsible for providing services such as:

- Proactive patrol of the campus and its facilities
- Investigation and reporting of crimes and incidents
- Motor vehicle traffic and parking enforcement
- Crime and security awareness programs
- Alcohol/Drug abuse awareness/education
- Self defense classes
- Consultation with campus departments for safety and security matters
- Additional services to the campus community such as: vehicle unlocks and jumpstarts, community safe walks (escorts), authorized after-hours building and office access, and assistance in any medical, fire, or other emergency situation.

The police officers employed by the Department of Public Safety are fully trained police officers in accordance with the Peace Officer Standards and Training (P.O.S.T.) Board and the Colorado Revised Statute.

More information on the Mines Police Department is available at: https://www.mines.edu/campus-safety/

Student Publications

Two student publications are published at CSM by the Associated Students of CSM. Opportunities abound for students wishing to participate on the staffs. A Board of Student Media acts in an advisory capacity to the publications staffs and makes recommendations on matters of policy.

The *Oredigger* is the student newspaper, published weekly during the school year. It contains news, features, sports, letters and editorials of interest to students, faculty, and the Golden community.

The literary magazine, *High Grade*, is published each semester. Contributions of poetry, short stories, drawings, and photographs are encouraged from students, faculty and staff.

Veterans Services

The Registrar's Office provides academic certification services for veteran students attending the School and using educational benefits from the Veterans Administration. Additional non-academic services are provided through the Dean of Students Office.

Activities

Student Activities, Involvement, and Leadership (SAIL)

Student Activities, Involvement, and Leadership (SAIL) coordinates the various activities and student organizations on the Mines campus. Student government, professional societies, living groups, honor societies, interest groups and special events add a balance to the academic side of the CSM community. Participants take part in management training, event planning, and leadership development. To obtain an up-to-date listing of the recognized campus organizations or more information about any of these organizations, contact the SAIL office.

Student Government

The Associated Students of Colorado School of Mines (ASCSM) is sanctioned by the Board of Trustees of the School. The purpose of ASCSM is, in part, to advance the interest and promote the welfare of CSM and all of the students and to foster and maintain harmony among those connected with or interested in the School, including students, alumni, faculty, trustees and friends. Undergraduate Student Government (USG) and Graduate Student Government (GSG) are the governing bodies recognized by Mines through ASCSM as the representative voice of their respective student bodies. The goal of these groups is to improve the quality of education and offer social programming and academic support.

Through funds collected as student fees, ASCSM strives to ensure a full social and academic life for all students with its organizations, publications, and special events. As the representative governing body of the students ASCSM provides leadership and a strong voice for the student body, enforces policies enacted by the student body, works to integrate the various campus organizations, and promotes the ideals and traditions of the school.

The Mines Activity Council (MAC) serves as the campus special events board. The majority of all-student campus events are planned by MAC. Events planned by MAC include comedy shows to the campus on most Fridays throughout the academic year, events such as concerts, hypnotists, and one time specialty entertainment; discount tickets to local sporting events, theater performances, and concerts, movie nights bringing blockbuster movies to the Mines campus; and E-Days and Homecoming.

Special Events

Engineering Days festivities are held each spring. The three day affair is organized entirely by students. Contests are held in drilling, hand-spiking, mucking, and oilfield olympics to name a few. Additional events include a huge fireworks display, the Ore-Cart Pull to the Colorado State Capitol, the awarding of scholarships to outstanding Colorado high school seniors and a concert.

Homecoming weekend is one of the high points of the year. Events include a football rally and game, campus decorations, election of Homecoming queen and beast, parade, burro race, and other contests.

International Day is planned and conducted by the International Student Council and the International Student and Scholar Services Office. It includes exhibits and programs designed to further the cause of understanding among the countries of the world. The international dinner and entertainment have come to be one of the campus social events of the year.

Outdoor Recreation Program

The Outdoor Recreation Program is housed at the Student Recreation Center. The Program teaches classes in outdoor activities; rents mountain bikes, climbing gear, backpacking and other equipment; and sponsors day and weekend activities such as camping, snowshoeing, rock climbing, and mountaineering.

Residence Hall Association (RHA)

Residence Hall Association (RHA) is a student-run organization developed to coordinate and plan activities for students living in the Residence Halls. Its membership is represented by students from each residence hall floor. Officers are elected each fall for that academic year. For more information, go to RHA.

Student Organizations

For a complete list of all currently registered student organizations, please visit the Student Activities office or website at https://studentactivities.mines.edu/.

Social Fraternities and Sororities – There are seven national fraternities and four national sororities active on the CSM campus. Fraternities and Sororities offer the unique opportunity of leadership, service to one's community, and fellowship. Greeks are proud of the number of campus leaders, athletes and scholars that come from their ranks. Colorado School of Mines chapters are:

- Alpha Phi
- Alpha Tau Omega
- Beta Theta Pi
- Kappa Alpha Theta
- Kappa Sigma
- Phi Gamma Delta
- Pi Beta Phi
- Sigma Alpha Epsilon
- Sigma Kappa
- Sigma Nu
- Sigma Phi Epsilon

Honor Societies – Honor societies recognize the outstanding achievements of their members in the areas of scholarship, leadership, and service. Each of the CSM honor societies recognizes different achievements in our students.

Special Interest Organizations – Special interest organizations meet the special and unique needs of the CSM student body by providing co-curricular activities in specific areas.

International Student Organizations – The International Student Organizations provide the opportunity to experience a little piece of a different culture while here at Mines, in addition to assisting the students from that culture adjust to the Mines campus.

Professional Societies – Professional Societies are generally student chapters of the national professional societies. As a student chapter, the professional societies offer a chance for additional professional development outside the classroom through guest speakers, trips, and interactive discussions about the current activities in the profession.

Additionally, many of the organizations offer internship, fellowship and scholarship opportunities.

Recreational Organizations – The recreation organizations provide the opportunity for students with similar interests to participate as a group in these recreational activities. Most of the recreational organizations compete on both the local and regional levels at tournaments throughout the year.

International Student Services

The International Student and Scholar Services Office (ISSS) serves approximately 850 international students and 150 scholars from 80 countries.

The ISSS provides the following services:

- Provide student orientation for incoming international undergraduate, graduate, and exchange students.
- Issue initial immigration documents used to attain a U.S. visa for study or scholarly activities.
- Advise on immigration regulations by individual appointment and group seminars.
- Prepare legal documents that allow international students to attain work authorization and gain work experience.
- Provide forms required by international students and their dependents to travel outside of the United States.
- Advise various international student groups, such as the International Student Council and fourteen student associations.
- Provide key pre-departure and arrival information for incoming students and their dependents.
- Oversee the international scholarship program.
- Management of the international scholar program. Provide initial immigration documents and scholar orientation.

The ISSS office also sponsors events and programs to help students adjust to life in the United States and at Mines. International Student and Scholar Services also provides advising related to emergencies and unexpected immigration problems.

If you have questions about international admissions, degree programs, billing, financial aid, or housing, please visit those specific Colorado School of Mines web pages. Please send other questions and comments about international student life at Colorado School of Mines to isss@mines.edu

For more information see www.isss.mines.edu

Multicultural Engineering Program

The Multicultural Engineering Program (MEP) is located at 1700 Maple Street in Coolbaugh House - the house between Mines Market at the Student Rec Center. MEP is committed to supporting traditionally underrepresented and first-generation students in science, technology, engineering, and math disciplines. We work to build a community of equity, inclusion, and support through professional development workshops, tutoring, scholarships, research and internship opportunities, cultural celebrations, and connections to professional societies. MEP also contributes to the recruitment, retention, and graduation of students historically underrepresented in STEM and provides professional development as related to equity and inclusion to students, staff, and faculty. MEP House is open to all students and has computers, free printing, school supplies, a student kitchen, and a prayer/meditation room.

MEP supports the following professional societies and student organizations: American Indian Science and Engineering Society (AISES), National Society of Black Engineers (NSBE), Out in Science, Technology, Engineering and Mathematics (oSTEM), Society of Asian Scientists and Engineers (SASE), the Society of Hispanic Professional Engineers (SHPE), and Kickstart.

American Indian Science and Engineering Society (AISES) is a nonprofit national organization that represents American Indians and Alaskan Natives in engineering, science, and other related technology disciplines. The mission of AISES is to substantially increase the representation of American Indians and Alaskan Natives in engineering, science, and other related technology disciplines. Through the quality and reach of its programs and the longevity and devoted commitment of its “family,” AISES is the undisputed leader in STEM opportunity in Indian Country. Members from over 200 tribal nations are represented within AISES, and AISES enjoys the support and partnership of corporate, government, academic, and tribal decision-makers.

Kickstart is a student organization at the Colorado School of Mines dedicated to building an inclusive community that enables the sharing and exploration of diverse identities. In the past we’ve held a variety of events surrounding DI&A such as a discussion about AAPI Hate and a tech-equity focused Hackathon through the Computer Science Department. We work with many organizations including Fraternity and Sorority Life, the Arthur Lakes Library, and the Multicultural Engineering Program. Our current goals are to build a sustainable vehicle for DI&A efforts at Mines while also empowering Kickstart members to develop the skills necessary for creating social impact.

National Society of Black Engineers (NSBE) is dedicated to the success of African-American engineering students and professionals. NSBE offers its members leadership training, professional development activities, mentoring opportunities, career placement services and more. NSBE’s mission is “to increase the number of culturally responsible Black engineers who excel academically, succeed professionally and positively impact the community.” The NSBE torch symbolizes the organization’s everlasting, burning desire to achieve success in this competitive society and to effect positive change in the quality of life of all people. The goal of the Society is to replicate its mission and vision in countries around the world, creating a global network of Black engineers, scientists and technologists. NSBE has accomplished more for Black engineering students than any other organization in the world.

Out in Science, Engineering, Technology & Mathematics (oSTEM) is a national society dedicated to educating and fostering leadership for LGBTQA communities in the STEM fields. The Mines Chapter of oSTEM, formerly GLBTA Engineers: Sigma Lambda, is a community driven club in place to give support to gay, lesbian, bisexual, and transgender students at Mines. We hold events for both out members, as well as to educate the Mines campus. We offer many opportunities for students to become involved with our chapter through weekly meetings, social events, and advocacy. This is a great challenge-by-choice organization in which you can decide which activities you want to participate in and which ones you may not want to. Additionally, this organization offers various professional meetings with companies and prepares students with easily transferrable communication and problem-solving skills.

Society of Asian Scientists and Engineers (SASE) is dedicated to the advancement of Asian heritage scientists and engineers in education and employment so that they can achieve their full career potential. In addition to professional development, SASE also encourages members to contribute to the enhancement of the communities in which they live. SASE membership is open to men and women of all ethnic backgrounds. SASE's mission is to prepare Asian heritage scientists and engineers for success in the global business world, celebrate diversity on campuses and in the workplace, and provide opportunities for members to make contributions to their local communities.

Society of Hispanic Professional Engineers (SHPE) is a nonprofit organization that exists for the advancement of Hispanic engineering students to become professional engineers and scientists, to increase the number of Hispanics entering into the field of engineering, and to develop and implement programs benefiting Hispanics seeking to become engineers and scientists. Anyone interested in joining may do so. Mission: SHPE changes lives by empowering the Hispanic community to realize its fullest potential and to impact the world through STEM awareness, access, support and development. Vision: SHPE's vision is a world where Hispanics are highly valued and influential as the leading innovators, scientists, mathematicians and engineers.

For further information, visit mep.mines.edu or contact:

Dra. Stepheny Beauchamp, Director, Multicultural Engineering Program
Colorado School of Mines
1700 Maple Street
Golden, CO 80401
303-273-3021
sbeauchamp@mines.edu

Office of Global Education (OGE)

The Office of Global Education (OGE) fosters and facilitates international linkages, cultural exchange, and the development of international expertise across all sectors of the University. OGE is responsible for study overseas through exchange and education abroad programs and offers immigration and orientation services for international students and scholars who study and work at Mines.

OGE is located in the Green Center, Room 219. For specific information about study abroad and other international programs, contact OGE at 303 273-3210 or visit the OGE web page at https://www.mines.edu/global.

The office works with the departments of the school to:

1. Promote internationalization of Mines' curricular programs and activities.
2. Help develop and facilitate study abroad opportunities for Mines students while serving as an informational and advising resource for them.
3. Assist in attracting new international students to Mines.
4. Serve as a resource for faculty and scholars of the Mines community, promoting faculty exchanges, faculty-led study abroad, and the pursuit of collaborative and bilateral exchange agreements.
5. Facilitate arrangements for official international visitors to Mines.

Office of Women in Science, Engineering and Mathematics (WISEM)

The Women in Science, Engineering, and Mathematics (WISEM) program office is located at 1710 Illinois Street.

Mission: The WISEM Program advocates and strives for an inclusive and equitable environment for women students, faculty and staff by enhancing opportunities and providing programming for the Mines community.

Vision: To lead campus in enhancing women's experiences at Mines by

- preparing students for successful, sustainable, rewarding careers.
- equipping Mines employees with professional success and advancement opportunities.
- providing all members of the Mines community with educational opportunities and resources that contribute to an inclusive and welcoming campus environment.

The office sponsors programs and services for the Mines community regarding gender and equity issues, and produces the Chevron Lecture Series, Women's History Month events, and the Continuum. The Society of Women Engineers (SWE) falls under the WISEM umbrella, and is a student run organization. The WISEM Director serves as an advisor to SWE. WISEM also administers the Caldwell and Vanguard Communities of Scholars and supports departmental women professional student groups, women faculty groups, women employee groups (EMPOWER and W-MCA) and the Women of Mines Alumni Interest Group.

For additional information, contact:

Kelly Olson
Associate Director
Women in Science, Engineering and Mathematics Program
SWE Faculty Advisor
303-273-3146
knechtel@mines.edu
https://wisem.mines.edu

Tuition, Fees, Financial Assistance, Housing & Dining Rates

Tuition, Fees, Financial Assistance, Housing & Dining Rates

Tuition and fees are established by the Board of Trustees of Colorado School of Mines following the annual budget process and action by the Colorado General Assembly and Governor.

Tuition

The official tuition and approved charges for the academic year will be available prior to the start of the academic year and can be found online on the Bursar's website.

Fees

The official fees, approved charges, and fee descriptions for the academic year will be available prior to the start of the academic year and can be found online on the Bursar's website.

Housing & Dining Rates

Room and board charges are established by the Board of Trustees and are subject to change. Payment of room and board charges falls under the same guidelines as payment of tuition and fees. For more information, go to Resident Life's website or Mines Dining.

Payments and Refunds

Financial Responsibility

It is the student's responsibility to abide by Mines payment and refund policies when registering for classes.

- Full payment of tuition and fees are due by 4 p.m. MST on the first business day following Census Day for each term. Please see the Bursar's website for specific semester information.
- Students are responsible for viewing their account balance online through Trailhead. Mines generates electronic invoices only, no paper invoices will be mailed.
- Students are responsible for dropping their courses by the published drop deadline if they don't plan to attend. Failure to do so will result in charges incurred on the student account.

If you don't fulfill your financial obligations:

- Any unpaid balance at 4 p.m. MST on the due date will be assessed a 1.5% late fee.
- An additional 1.5% late fee will be assessed to any unpaid balance each month thereafter.
- Accounts not paid in full by the last day to drop classes are considered past due. Holds will be placed on past due accounts preventing registration, transcripts, diplomas, and access to other student records.
- Accounts not paid in full at the end of each semester are considered delinquent. Delinquent accounts will be turned over to a collections agency in accordance with Colorado law and all collection fees and costs will be added to the account balance. The collection agency may report delinquent accounts to the national credit bureau.
- Students whose accounts have been sent to a collection agency must pay their balance in full and prepay for any subsequent semester before registration will be allowed.
- Any students whose debt to Mines was written off due to a bankruptcy discharge will be required to prepay for future semesters before registration will be allowed.

Refunds

The amount of tuition and fee assessments is based primarily on each student's enrolled courses. In the event a student withdraws from a course or courses, assessments will be adjusted as follows:

- If withdrawal from a course or courses is made prior to the end of the add/drop period for the term of enrollment, as determined by the Registrar, tuition and fees will be adjusted to the new course level without penalty.
- If withdrawal from a course or courses is made after the add/drop period, regardless of whether or not the student officially withdraws from Mines, no adjustments in charges will be made.

Please note: students receiving federal financial aid under the Title IV programs may have a different refund as required by federal law or regulations.

Room and board refunds are pro-rated to the date of checkout from the Residence Hall. Arrangements must be made with the Housing Office.

Student health insurance charges are not refundable. The insurance remains in effect for the entire semester.

Late Fee for Application to Graduate after Stated Deadlines – $250

Undergraduates:

The deadline to apply to graduate and participate in commencement is the first day of class of the term in which the student intends to graduate/participate.

Any request to be added to the graduation list and/or commencement ceremony after the first day of class (and before November 10th for fall or April 10th for spring and summer) may be made in writing and will be considered by the Registrar's Office. If the request is denied, the student will be required to apply for the next available graduation/ceremony. If the request is approved and all other conditions are met (i.e. degree requirements can be met, required forms are turned in, and outstanding hours limitations are not exceeded), a mandatory $250 fee will be applied to the student's account. This fee cannot be waived and cannot be refunded if the student does not meet the graduation checkout deadlines.

For late requests that are approved, tickets to the commencement ceremony for family and friends of the graduate are not guaranteed, as they may have already been distributed or assigned. Additionally, the student's name may not appear in the commencement program due to publishing deadlines.

No undergraduate student will be added to a graduation or commencement when the request is made after November 10th for the fall commencement (which includes December graduation), or April 10th for the spring and summer commencement ceremony (which includes May and August graduations).

College Opportunity Fund

The College Opportunity Fund provides State financial support to eligible students for higher education. It was created by an Act of the Colorado State Legislature and signed into law by Governor Owens in May 2004.

What does it mean? In the past, the State gave money directly to the colleges. Now, if you authorize use of the stipend for any given term, the college you are attending will receive the funding, and you will see it appear as a credit on your tuition bill.

Who is eligible? Undergraduate students who are eligible for in-state tuition, and who apply for COF, are admitted to and enrolled in an eligible institution of higher education, and who authorize the institution to collect the funds on their behalf. Once enrolled at the Colorado School of Mines, the student must authorize the school to collect these funds from the state on the student's behalf. Once authorized, the school will continue to collect these funds on the student's behalf unless and until the student chooses to revoke the authorization.

How much is the stipend? It will vary. The amount will be determined each year by the Colorado Legislature.

For additional information please refer to:

Colorado School of Mines website: https://www.mines.edu/registrar/college-opportunity-fund/

Colorado Department of Higher Education's website: https://highered.colorado.gov/Finance/COF/default.html

The College Opportunity Fund website: https://cof.college-assist.org/

Financial Aid and Scholarships

Undergraduate Student Financial Assistance

The role of the Mines Financial Assistance Program is to assist students to enroll and complete their education. Please visit the financial aid website for more information on how financial aid works, current costs and other processing questions at https://finaid.mines.edu/. Financial aid is only able to pay towards courses that will count towards a student current degree program. Students must be enrolled in at least half-time in those courses to be eligible for aid.

Applying for Assistance

The Mines Application for Admission serves as the application for merit-based scholarships for new students. Students will receive information regarding additional scholarship applications once admitted. Continuing students may be recommended by their major department for scholarships designated for students from that department. To apply for need-based Mines, Federal and Colorado assistance, students should complete the Free Application for federal student aid.

Once evaluated, a financial aid award notification will be sent to the student. New students can anticipate award notification by early January via email and US mail. Continuing students will be notified in early June via their Mines email.

Types of Financial Assistance

Need-based assistance will typically include grants, part-time employment, and student loans. Grants are provided by Mines, by the state of Colorado (Colorado State Grants), and by the federal government (Pell Grants and Supplemental Educational Opportunity Grants).

Work Study funds also come from Mines, state of Colorado and the federal government. Students work between 8 and 10 hours a week, and typically earn between $500 to $1,500 to help pay for books, travel, and other personal expenses.

Student Loans may be offered from the direct lending program through the federal government. Mines offers a limited amount of institutional loans to assist students during the summer.

Supplemental student loans may also be offered through private bank loan programs.

Merit-based assistance is offered to incoming first year students to recognize them for their outstanding achievements. Awards to new first year students are made on the basis of their academic performance in high school as well as information on the admissions application such as outside activities. New transfer students who are seeking their first degree may be eligible for a merit award if they belong to Phi Theta Kappa. Continuing students can receive departmental scholarships based on their academic performance at Mines, particularly in their major field of study, and on financial need.

General Scholarship Application will be available for both incoming and continuing students. Incoming students will be informed of the application and how to log in during the admissions process. Continuing students will be notified in the Daily Blast once it is available. The General Scholarship Application link will be in Trailhead.

Alumni Association Grants are awarded to students who are children of alumni who have been active in the Mines Alumni Association for the two years prior to the student’s enrollment. The students may also receive a senior award, based on their academic scholarship, and the availability of funds.

Engineers’ Day Scholarships are available to Colorado residents. Based on high school records, an essay, and other information, a committee of Mines' students selects the recipients for these four-year awards. Students will be informed of the application during the admission process.

Athletic scholarships may be awarded to promising student-athletes in 16 men’s and women’s sports. The scholarships are renewable for up to three years, based on the recommendation of the Athletics Department.

Army ROTC scholarships are available from Mines and the U.S. Army for outstanding young men and women who are interested in a military career. The one, two, three, and four-year scholarships can provide up to full tuition and fees, a book allowance, and a monthly stipend for personal expenses. The Mines Military Science Department assists students in applying for these scholarships.

U.S. Navy Scholarships through the Civil Engineering Program, Nuclear Power Officer Program, and Baccalaureate Degree Completion Program are also available to Mines students. The local Navy Recruiting District Office provides information about these scholarships.

U.S. Air Force ROTC Scholarships are available from Mines and the U.S. Air Force. The three- and four-year scholarships can provide up to full tuition, fees, a book allowance, and a stipend. Further information is available through the Department of Aerospace Studies at the University of Colorado Boulder (the official home base for the Mines detachment).

In addition to scholarships through Mines, many students receive scholarships from their hometown civic, religious or other organizations. All students are urged to contact organizations with which they or their parents are affiliated to investigate such scholarships. The Financial Aid Office reserves the right, unless otherwise instructed by the student, to release the student’s information to scholarship providers for the purpose of assisting students in obtaining scholarships.

Financial Aid Policies

General

Students are required to report to the Financial Aid Office all financial assistance offered or received from all sources, including Mines, immediately upon receipt or notification of such assistance. For the purpose of this paragraph, “financial assistance” shall include, but not be limited to, grants, scholarships, fellowships, or loans funded by public or private sources, as well as all income not considered taxable income by the Internal Revenue Service. Upon receipt of this information, Mines shall evaluate, and may adjust any financial assistance provided to the student from Mines, Colorado, or federal funds. No student shall receive financial assistance from Mines if such student’s total assistance from all sources exceeds the total cost of the student’s education. For the purpose of this paragraph, the “total cost of education” shall be defined to include the cost of tuition, fees, books, room and board, transportation, and personal expenses.

Funds for the Federal Pell Grant, Federal Supplemental Educational Opportunity Grant, Federal College Work-Study Program, Federal Direct Stafford Loan, and Federal Direct PLUS Loans are provided in whole or part by appropriations of the United States Congress. The Colorado General Assembly provides funds for the Colorado Grant and Colorado Work-Study programs. These programs are all subject to renewed funding each year.

Financial aid is only able to pay towards courses that will count towards a student current degree program. Students must be enrolled in at least half-time in those courses to be eligible for aid.

Satisfactory Academic Progress

Mines students receiving scholarships must make satisfactory academic progress as specified in the rules and regulations for each individual scholarship.

Students receiving assistance from federal, Colorado, or need-based Mines funds must make satisfactory academic progress toward their degree. Satisfactory progress is defined by maintaining adequate pace toward graduation and maintaining a 2.0 cumulative GPA at all times. Pace is measured by dividing the overall credit hours attempted by the overall credit hours completed. Students will be required to maintain a 75% completion rate at all times. Satisfactory standing is determined after each semester, including summer. If students are deficient in either the pace or grade-point average measure, they will receive a one-semester warning period during which they must return to satisfactory standing.

If this is not done, their eligibility will be terminated until such time as they return to satisfactory standing. Financial aid eligibility termination may be appealed to the Financial Aid Office on the basis of extenuating or special circumstances having negatively affected the student's academic performance. If approved, the student will receive a probationary period of one semester to regain satisfactory standing.

Study Abroad

Students wishing to pursue study abroad opportunities should contact the Office of Global Education (OGE). Colorado School of Mines encourages students to include an international study/work experience in their undergraduate education. Mines maintains student exchange programs with a wide variety of institutions. Courses successfully passed abroad can be substituted for their equivalent course at Mines. Overall GPA is not affected by courses taken abroad. A well-planned study abroad program will not delay graduation. In addition, study abroad can be arranged on an individual basis at universities throughout the world.

Financial aid and selected scholarships and grants can be used to finance approved study abroad programs where hours toward the student's program will be transferred to Mines. The OGE has developed a resource center for study abroad information, abroad@mines.edu. Students are invited to use the resource materials and meet with staff to discuss overseas study opportunities.

Withdrawals

We understand that unexpected events occur in life that will cause a student to withdraw from classes at Colorado School of Mines. Federal regulation requires financial aid to be awarded under the assumption that a student will attend the institution for the entire period in which federal assistance was disbursed. The following policies will help you understand the impact a withdrawal may have if you are receiving financial aid. The tuition and fees refund policy set by Mines is separate from the return calculation required by federal regulation.

An official withdrawal will be recorded once the withdrawal process has been completed by the student. Students who withdraw from the university should contact the Financial Aid Office as part of the withdrawal process to determine what effect this will have on their financial aid. A withdrawal requires the financial aid office to determine how much of the federal, state and institutional financial aid the student has earned. Financial aid is not considered earned until the 60% point of the semester. The unearned portion will be returned to the program from which it came (i.e. student loans to the lender, Pell to the federal Department of Education, etc.). Students need to be aware that they may owe Colorado School of Mines for unearned federal, state and/or institutional aid even if they are receiving a refund in tuition and fees.

Federal regulations consider a student to be an unofficial withdrawal if the student receives all failing grades for the term. If the student has not completely withdrawn and has failed to earn a passing grade in at least one class for the term, Mines is required to determine whether the student established eligibility for financial aid by attending at least one class or participating in any Mines academic-related activity. An unofficial withdrawal calculation will be performed and funds returned to their respective federal, state and/or institutional aid programs if there is not documentation supporting the student's last day of attendance, or the documentation indicates the student stopped attending prior to the 60% point of the semester.

State of Colorado Residency Qualifications

A student is classified as a resident or nonresident for tuition purposes at the time admission. The classification is based upon information furnished by the student. If the information furnished by the student classifies them as nonresident and they believe they should be resident, they are granted the option to complete the Tuition Classification form which is located in their applicant portal. Questions on this form can be answered by the Admissions Office at admissions@mines.edu.

A student who remains classified as nonresident, and who is able to fulfill residency requirements based on the Colorado state law on Tuition Classification, becomes eligible for resident tuition after enrolling at Mines and must complete a petition through the Registrar's Office. More information on residency requirements and what petition to complete can be found on the residency website.

Petitioning for In-State Tuition Classification

The specific requirements for establishing residency for tuition classification purposes are prescribed by state law (Colorado Revised Statutes, Title 23, Article 7). Because Colorado residency status is governed solely by Colorado law, the fact that a student might not qualify for in-state status in any other state does not guarantee in-state status in Colorado. The Tuition Classification statute places the burden of proof on the student to provide clear and convincing evidence of eligibility for residency. The final decision regarding tuition status rests with the Residency Appeals Committee of Colorado School of Mines. A student who willfully gives wrong information to evade payment of nonresident tuition shall be subject to serious disciplinary action.

There are three components to determining residency eligibility:

- **Emancipation** means a student's parents have entirely surrendered care, custody, and support of the student. The student is able to independently support themselves. Support of any kind from family and/or friends does not make a student emancipated. Emancipation must occur at least one year before a student can establish 12 months of domicile and intent.
- **Domicile** is a person’s true, permanent home and place of habitation and must be established at least 12 consecutive months prior to the first day of classes.
- **Intent** is the legal ties a person has established to make Colorado their permanent home and must be established concurrently while establishing domicile. This means a student must sever ties from their former state and establish these ties in Colorado. This would include: license, voter registration, vehicle registration, and filing state taxes like any other resident of the state.

To be able to establish domicile and intent, an undergraduate student must be a "qualified person" under one of the following categories: parent/legal guardian, adult (22 years old to begin domicile period, but must be 23 years of age before the term they petition for), or if the student is under 22 years old they must be legally emancipated.

More information on how to qualify and petition for resident status, as well as deadlines, can be found on the residency website.

Residence Halls

Housing & Dining

Room and board charges are established by the Board of Trustees and are subject to change. Payment of room and board charges falls under the same guidelines as payment of tuition and fees. Current rates can be found by going to Residence Life Rates.

Housing Application

Information and application for residence hall space can be found in your applicant portal. Colorado School of Mines has a first-year residency requirement. All housing assignments are based on the date of the enrollment deposit with Admissions.

After the first year, sophomore students are invited to live in our sophomore housing communities in Maple Hall and 1750 Jackson. Residence Life also encourages upper-class and graduate students to apply to the Apartments at Mines Park. Additionally, students associated with fraternity and sorority life may apply for housing through Residence Life in partnership with Fraternity and Sorority Life (within SAIL). The submission of a room application for all housing areas can be done in Trailhead.

Contracts are issued for the full academic year and no cancellation will be accepted after an agreement has been submitted, except for those who decide not to attend Colorado School of Mines. Those contracts separately issued only for students entering second semester may be canceled no later than December 1. After that date no cancellation will be accepted except for those who decide not to attend Mines.

Housing & Dining

Residence Halls

Residence hall living is an integral part of the Colorado School of Mines experience. All first-year students are required to live on campus in the residence halls. Most sophomores and many upper-class students continue to live in Residence Life housing throughout their time at Mines in different communities that meet their needs.

The traditional residence halls (Morgan, Thomas, Bradford, and Randall) house about 380 first-year students in single and double rooms on single-gender floors, with a community-style bathroom facility on each floor. Weaver Towers has living space for 230 first-year students in suites with single and double rooms, a common living area, and two single bathroom facilities. Maple Hall is a 290-bed suite-style facility with single and double bedrooms and a few triple rooms. Maple has a semi-private bathroom in each suite shared by one other room. Elm Hall is a neighborhood-style facility offering space for 210 students in mostly double rooms, with a limited number of single and triple rooms. Elm has several community bathrooms that offer private options on each floor. Spruce Hall is our newest residence hall, housing 400 first-year students, with single, double, and triple bedrooms in a traditional community style building with community bathrooms that are gender-inclusive. Elm Hall and Spruce Hall are both options for gender-inclusive housing, although students of any gender identity are welcome in all of our residential spaces.

All residence halls have kitchens, study lounges, social lounges, laundry facilities, and a front desk to help with packages and to provide services to our residents. All residence hall bedrooms are equipped with a twin extra-long, loftable bed, a desk, a chair, a dresser, and a closet space for each student, as well as wired and wireless internet connections, and unlimited laundry. Students are responsible for damage to the room or furnishings. Colorado School of Mines assumes no responsibility for loss or theft of personal belongings, and residents are strongly encouraged to carry personal property or renters' insurance.

Additionally, Residence Life offers students an option to live and learn within a Signature Learning Community that is a partnership between Residence Life, administrative and academic departments, and faculty across campus. They serve as a way for students to enhance their living experience on campus. Signature Learning Communities are different kinds of communities that share different missions. There are three types of Signature Learning Community, Theme Learning Communities, Living Learning Communities, and Affinity Communities. Theme Learning Communities consist of intentionally designed living experiences centered around a variety of educational, cultural, organizational, and personal interests. These communities allow students with common interests to live together and support each other through planned activities and informal interactions and to build relationships with faculty outside the classroom through the Faculty Friend program. Living Learning Communities are made up of students who all share a membership in a common curricular experience. Affinity communities are smaller communities comprised of students who share a connection in common around identity. We encourage you to explore the options that are possible in our Signature Learning Community program on our website by clicking here.

For all housing and dining rates, please see the Housing Rates web page.

Mines Dining

Mines Dining operates a main dining hall, Mines Market, and five retail dining facilities on campus. Mines Market features all-you-care-to-eat dining, adjacent to Elm Hall. Additional retail dining facilities include the Periodic Table (featuring Starbucks, Qdoba, WOW (burgers, chicken sandwiches, and more), and a convenience store) in the Student Center, a dining location in the Student Recreation Center, Brown Hall, Einstein Bros. Bagels in the Beck Venture Center, and Zime Cafe in Spruce Hall. All take student meal plans, as well as cash or credit card. Residence hall students are required to maintain a resident meal plan. Meal plans are designed to be flexible in order to best serve our student's needs.

Students not living in a residence hall may purchase any one of several voluntary meal plans which best meets their individual needs. Dining options are limited during breaks (Thanksgiving, fall, winter and spring break). For more information and hours, go to https://www.mines.edu/student-life/blastercard/.

For rates, please see the Residential Meal Plans page.

Housing beyond the first year in on campus apartments

Mines is proud to offer housing to students beyond their first year in a variety of locations and housing options.

1750 Jackson is a sophomore living apartment community on the east side of campus. 1750 Jackson houses 360 students in their second year, creating options for students to live independently while living with their friends in a Residence Life supported environment. 1750 Jackson has fully furnished apartments (Twin XL loftable bed and mattress, desk, chair, dresser, couch, chair, coffee table, and stools) with kitchens for four students, living in either double or single bedrooms. There are also single studio apartments available in limited quantity. 1750 Jackson residents have wired and wireless internet connections, laundry on each floor, and indoor and outdoor common areas for studying, relaxing, and fun.

The Mines Park apartment community is located just west of the main campus on 55 acres owned by Mines. The complex houses upper-class undergraduate students, graduate students, and students with partners and families. Mines Park is in the middle of a very intentional redevelopment project that includes new buildings and renovation of current apartment units. Mines Park units are complete with refrigerators, stoves, dishwashers, wired and wireless internet connections, laundry, and a Mines Park parking pass. Most units are not furnished. Starting in the 2025-2026 academic year, all units will be furnished and parking will no longer be included in rent. Currently, Mines Park has a community center that contains laundry facilities, recreational and study space, and meeting rooms. For more information or to apply for apartment housing, go to the Mines Park webpage.

Residents of our apartment communities must be full-time students. Student and professional staff live within each community for any assistance, advice, support, and community building as well as emergency response.

For all housing and dining rates, please see the Housing Rates page.

Fraternities and Sororities

Any non-freshman student who is a member of one of the national Greek organizations with a house on campus is eligible to live in Fraternity or Sorority housing after their freshman year. Several of the Greek houses are owned and operated by the school, while the remaining houses are owned and operated by the organizations. All full-time, undergraduate students are eligible to join these organizations. For information, visit the Fraternity and Sorority Life office.

Undergraduate Information

Undergraduate Catalog

It is the responsibility of the student to become informed and to observe all regulations and procedures required by the program the student is pursuing. Ignorance of a rule does not constitute a basis for waiving that rule. The Undergraduate Catalog, current at the time of the student's most recent admission, gives the academic requirements the student must meet to graduate. However, a student can change to the requirements in a later catalog published while the student is enrolled as an undergraduate. Changes to administrative policies and procedures become effective for all students as soon as the campus community is notified of the changes. The Undergraduate Catalog is available to students in electronic format. Electronic versions of the Undergraduate Catalog may be updated more frequently to reflect changes approved by, and communicated to, the campus community. As such, students are encouraged to refer to the most recently available electronic version of the Undergraduate Catalog. This version is available at the Mines website. The electronic version of the Undergraduate Catalog is considered the official version of this document. In case of disagreement between the electronic and print versions (if available), the electronic version will take precedence.

***Beginning in Fall 2024, the undergraduate catalog will incorporate course-level learning outcomes. While the learning outcomes presented in this edition of the catalog may be outdated, they will be revised and ensured for accuracy in subsequent updates.**

Admission Requirements

Colorado School of Mines seeks to admit a diverse and dynamic class of first-year and transfer students, representative of the state of Colorado, the nation and beyond.

Learn more about undergraduate admissions considerations, requirements and deadlines.

Returning Students

Colorado School of Mines welcomes previous Mines students wishing to resume their studies at Mines. Students must provide official transcripts from other college and universities attended since last attending Mines.

Learn more about the readmissions process.

Exchange Students

Please refer to the Office of Global Education website for up-to-date information on the Mines Exchange Program.

International Students

For purposes of admission, international applicants are students in a non-immigrant status who are not U.S. citizens or do not have approved and finalized U.S. permanent residence, refugee status or political asylum. International students usually need an F1 or J1 visa to study in the United States.

Learn more about international first-year admissions and requirements, including language proficiency.

Learn more about international transfer admissions and requirements, including language proficiency.

Enrollment Requirement – All Admitted Students

All admissions are ultimately contingent upon successful completion and submission of final, official transcripts reflecting academic achievement similar to assessment at the time of admission. Students are expected to continue to prepare at a similar level of academic rigor, and with similar or better results as the enrollment date approaches. If final transcripts/documents are received that reflect information different from the admission assessment, Colorado School of Mines reserves the right to review the admission offer again, and to take appropriate action. This may include a change in conditions or terms of admission, or a rescission of the admission offer. An individual who receives a dismissal has the right to appeal the decision to the committee on academic policy and procedure, whose decision will be final.

Fraudulent Applications

Individuals who withhold or provide fraudulent information on applications for undergraduate admissions or readmissions are subject to immediate dismissal from the university. The decision for immediate dismissal will be made by the associate provost of enrollment management and/or the executive director of admissions. This decision will be made after a complete and thorough review of the situation and an individual conference with the student involved. The individual dismissed has the right to appeal the decision to the committee on academic policy and procedure, whose decision will be final.

Non-degree Students

Our undergraduate non-degree option is designed for students who are interested in taking courses at Mines, but do not plan on pursuing a degree at that time. Registration in requested courses is based on availability (after all current students have registered for their courses), completion of the non-degree application, and proof of prerequisites, through the submission of official transcripts.

Learn more about the non-degree application process and requirements.

Academic Regulations

Deficiencies

The curricula at Colorado School of Mines have been specially designed so that the coursework flows naturally from course to course and year to year. Thus, it is important that deficiencies in lower-numbered courses be scheduled in preference to more advanced work.

Prerequisites

It is the responsibility of each student to make certain that the proper prerequisites for all courses have been met. Registration in a course without the necessary prerequisite may result in dismissal from the class or a grade of F (failed) in the course.

Remediation

The Colorado Department of Higher Education specifies a remedial programs policy in which any first-time freshman admitted to public institutions of higher education in Colorado with ACT (or equivalent) scores of less than 18 in reading or English, or less than 19 in mathematics, are required to participate in remedial studies. At the Colorado School of Mines, these remedial studies will be conducted through required tutoring in Nature and Human Values for reading and writing, and Calculus for Scientists and Engineers I for mathematics in which students must receive the consequent achievement of a grade of C or better.

Transfer Credit

In all cases, requests for transfer credit are processed by the registrar. Credits must be submitted on an official transcript from a regionally accredited institution or if the institution is international, credit is only considered from institutions that are recognized by the Ministry of Education or other official accrediting or recognition body in the country of origin. Credits must be academic in nature. Vocational, CLEP, DSST, and theological credit is not accepted. No credit is granted for internships, co-ops, practicums, life experience courses, Independent Study, precalculus courses below Calculus I such as trigonometry and geometry, and non-calculus based general/introductory Physics courses.

Only courses completed with grades of C or better will be considered for acceptance. Credit that is recorded as “pass,” “satisfactory,” or “credit” at institutions that do not equate this classification to a C or better grade will not transfer.

Departments may stipulate a higher minimum grade.

Credit Conversion

Quarter credits are converted to semester credits upon transfer. This is done by multiplying the quarter credits by 0.67 (i.e. 4 quarter credits x 0.67 = 2.6 semester credits).

European Credit Transfer and Accumulation System (ECTS) credits are converted to semester credits by multiplying ECTS credits by 0.5 (i.e. 2 ECTS x 0.5 = 1 semester credit),

Other international credits are converted to the U.S. semester-based system according to national standards set by AACRAO International Education Services.

New Transfer Students

Upon matriculation, a transfer student will receive the prescribed academic credit for courses taken at another institution if these courses are listed in a current articulation agreement and transfer guide between Mines and that institution. When an articulation agreement does not exist with another institution, the transfer student may receive credit for a course taken at another institution upon receipt of a certified copy of the student’s official transcript from the host institution. Courses may be subject to review by the appropriate Mines department head or designate to ensure course equivalency. Course materials, such as syllabi, exams, and notes may be requested for evaluation. Credits earned more than 10 years in advance of admission will not transfer.

Continuing Students

Students who are currently enrolled at Mines may transfer credit in required courses only in extenuating circumstances, upon the advance approval of the registrar, the department head of the appropriate course, and the department head of the student's option/major. Upon return, credit will be received subject to review by the registrar. Physics courses are subject to post-approval from the department. Forms for this purpose are available in the Registrar's Office, and the process is reviewed periodically by the Office of the Executive Vice President for Academic Affairs (EVPAA).

Returning Students

Students who have matriculated at Mines, withdrawn, applied for readmission, and wish to transfer in credit taken at an institution while they were absent from Mines must obtain approval, upon return, of the department head of the appropriate course, the department head of the student's option/major, and the registrar.

Prior Learning Credit

Colorado School of Mines makes no promises to prospective students regarding the acceptance of credit awarded by examination, credit for prior learning, or credit for transfer until these credits have been evaluated for applicability to a degree program. If prior learning credits are approved by Mines, up to a maximum of 56 credits of prior learning credit may be applied to an undergraduate degree based on course applicability for that degree.

Advanced Placement (AP) and International Baccalaureate (IB)

Coursework completed for select subjects under the Advanced Placement program in a high school may be accepted for college credit provided that the Advanced Placement program test grade is either a 5, 4, or 3 depending on the exam. For specific information, please visit the AP, IB, Challenge Exam and Military Credit website.

Coursework completed for select subjects under the International Baccalaureate program in high school may be accepted for college credit provided that the International Baccalaureate program exam grade in a 4, 5, 6, or 7 on selected standard and higher level exams. In some cases, departmental approval is required before credit is granted. More information on which subjects are accepted can be found on the AP, IB, Challenge Exam and Military Credit website.

Challenge Exams

Qualified students may complete challenge exams to test out of and receive credit for the following foundational core courses at Mines. Faculty in each department determine a student's eligibility for sitting for the exams and communicate eligibility requirements to the registrar for the purposes of communication with the new incoming eligible students.

CBEN110	FUNDAMENTALS OF BIOLOGY I	4.0
CHGN121	PRINCIPLES OF CHEMISTRY I	4.0
CSCI128	COMPUTER SCIENCE FOR STEM	3.0
PHGN100	PHYSICS I - MECHANICS	4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	4.0

Incoming students in their first two semesters at Mines may be eligible for challenge exams based on AP scores or other factors as determined by the department offering the exam. Other classes/subjects may be considered on a case-by-case basis.

Challenge exams are provided at the department's option and discretion. Departments are not required to provide exams for all introductory and foundational core courses.

Students must pass the challenge exam with the equivalent of a C grade or better as determined by the department in order to earn credit for the course. Passed exams are recorded as Mines credit with a grade of EX. Challenge exams do not affect the student's grade-point average at Mines.

Departments provide information about students who have passed exams to the Registrar's Office prior to Census Day in order to make necessary adjustments to the student's schedule.

Challenge exam credit may not be awarded if it is a repeat of already earned college-level credit.

Students will not be charged tuition for the exam, but Mines reserves the right to charge an administrative fee to take an exam. No fees are required at this time.

Additional details about these exams can be found on the relevant department's website.

Veterans

Colorado School of Mines is approved by the Colorado State Approving Agency for Veteran Benefits under chapters 30, 31, 32, 33, 35, 1606, and 1607. Undergraduate students must register for and maintain 12.0 credits, and graduate students must register for and maintain 9.0 credits of graduate work in any semester to be certified as a full-time student for full-time benefits. Any hours taken under the full-time category will decrease the benefits to ¾ time, ½ time, or tuition payment only.

All changes in hours, program, addresses, marital status, or dependents are to be reported to the Veterans Certifying Officer as soon as possible so that overpayment or underpayment may be avoided. Veterans must see the Veteran's Certifying Officer each semester to be certified for any benefits for which they may be eligible. In order for veterans to continue to receive benefits, they must make satisfactory progress as defined by Colorado School of Mines.

An honorably or generally discharged military veteran providing a copy of his/her DD214 is awarded two credits to meet the physical education undergraduate degree requirement at Mines. Additionally, veterans may request substitution of a technical elective for the institution's core EDNS course requirement in all undergraduate degree programs.

Students who have served or are currently serving in the military are eligible for priority registration beginning summer/fall 2018. Proof of service needs to be provided to the Registrar's Office and may include (but is not limited) to a DD-214 for veterans and for active-duty personnel current orders or other documents showing active-duty status.

For more information, please visit the Veterans Services web page.

Military Credit Policy

The evaluation of previous postsecondary education and training is mandatory and required for VA beneficiaries. For students utilizing Veterans benefits who are approved for transfer credit as a result of this evaluation, the institution will grant appropriate credit, reduce the program length proportionately, notify the student and Veterans Affairs in writing of this decision, and adjust invoicing of the VA accordingly.

Colorado School of Mines reviews the Joint Service Transcript and other military documents for transfer credit on behalf of our newly admitted and first semester active-duty military and veteran students. Academic coursework is considered for undergraduate credit from all branches of the military services including the United States Army, Navy, Air Force, Marines, and Coast Guard.

Credit is considered based on the submission of a Joint Services Transcript, a Community College of the Air Force transcript, and/or the military form DD214 by the student as part of the student's admissions application submission. Consideration of credit is guided by the standards set forth in the American Council on Education (ACE) recommendations with final transferability and applicability determined by Colorado School of Mines.

Only those courses that carry an academic designation will receive consideration for credit. Applicability of credit to a specific degree is determined based on the requirements of that degree. Most approved military credits will be free elective credits and will not be direct equivalents of courses offered at Colorado School of Mines. Be aware that if elective requirements are complete, this may limit the options for course selections during your program. This can be an issue for students who need to keep a full-time course load for VA benefits usage. Each student is encouraged to speak with the VA and Military Specialist in the Registrar's Office for further information about the regulations surrounding using VA benefits.

ELIGIBILITY

Within the guidelines of this policy, veteran students must meet the following criteria to be awarded transfer credit:

1. Admission to an undergraduate degree program at Colorado School of Mines.
2. Be a veteran with an honorable or general discharge, an active-duty service member, or a member of the Reserves/National Guard.
3. Provide official military records including the DD214 (if applicable) and the Joint Services Transcript (JST) during the admission process.

TRANSFER CREDIT COMPONENTS

A student with military training entering Mines may be eligible for up to 14 semester credits depending on their completed military academic coursework. Applicability of transfer credit to graduation requirements will vary depending on the chosen degree.

1. Up to 2 credits of Physical Activity

Students with military training who are able to provide a DD214 showing an honorable or general discharge will be awarded 2 credits (equivalent of 4 separate semesters) of physical activity credit. This credit will meet the requirement for the complete Physical Activity Requirement at Mines.

2. Up to 6 credits of Design

Depending on the content and duration of training and academic coursework, a veteran or active service member may apply to the Engineering, Design and Society Program for consideration of the transcripted JST credit and copy of the DD214 form to be transferred as a portion or all of the required first-level design course. If approved, the student would be awarded either:

- 2 semester credits toward the degree and would be required to complete EDNS155 (1 credit) instead of the complete EDNS151 (3 credit) course, or
- 3 semester credits toward the degree and the completion of the full EDNS151 (3 credit) course.

3. Up to 6 credits of Humanities & Social Science

4. Up to 6 credits of Free Elective

Courses listed on the JST may be considered for up to a maximum of 6 credits of Free Elective. These courses must be academic in nature and not occupational or career-based training. Evaluations are based on ACE recommendations and internal Mines evaluation of coursework.

In all cases, acceptable course credit must be academic in nature and cannot repeat or overlap other courses for which the student has degree credit.

Military and EDNS 151/2XX Exemptions

Students who have technical experience outside of the classroom may be eligible to substitute a different technical elective course in place of EDNS151 and EDNS251. In order to pursue this course of action, the student must provide information and materials describing the experience and how it applies to the program to the EDNS program director. If approved, the student will complete the substitution form and turn it in to the Registrar's Office to be placed in the academic file.

Course Withdrawals, Additions and Drops

Courses may be added or dropped without fee or penalty during the first 11 school days of a regular academic term (first four school days of a six-week field course or the first six school days of the eight-week summer term).

Continuing students may withdraw from any course after the eleventh day of classes through the thirteenth week for any reason with a grade of W. After the thirteenth week, no withdrawals are permitted except in cases of complete withdrawal from school or for extenuating circumstances (medical or legal hardship) under the auspices of the Dean of Students Office. In the case when a student completely withdraws after the stated deadline for course withdrawals, they may jeopardize their ability to immediately return to Mines the following semester (see Withdrawal from School, Mines Catalog). A grade of F will be given in courses which are withdrawn from after the deadline without approval.

Approval of a late withdrawal from a course can be given by the registrar acting on behalf of the Office of Academic Affairs in accordance with Mines' refund policy, and in compliance with federal regulations. Requests should be initiated in the Registrar's Office.

All adds/drops are initiated in the Registrar's Office. To withdraw from a course (with a W) a student can withdraw from a course in Trailhead by the thirteenth week deadline. If a student receives financial aid or Veteran's benefits, consult the Financial Aid Office and/or the VA representatives in the Registrar's Office prior to withdrawing from a course. Refer to the Academic Calendar for dates of specific deadlines.

Independent Study

For each semester, credit awarded for independent study a student is expected to invest approximately 25 hours of effort in the educational activity involved. To register for independent study, a student should get from the Registrar's Office the form provided for that purpose, have it completed by the instructor involved and the appropriate department head, and return it to the Registrar's Office.

Off-Campus Study

A student must enroll in an official Mines course for any period of off-campus, course-related study, whether U.S. or foreign, including faculty-led short courses, study abroad, or any off-campus trip sponsored by Mines or led by a Mines faculty member. The registration must occur in the same term that the off-campus study takes place. In addition, the student must complete the necessary release, waiver, and emergency contact forms, transfer credit pre-approvals, and FERPA release, and provide adequate proof of current health insurance prior to departure. For additional information concerning study abroad requirements, contact Global Education at 303-273-3210; for other information, contact the Registrar's Office.

Absenteeism

Introduction

Mines students are expected to fulfill their academic requirements through attendance and/or participation. Class attendance is required of all students unless the student has an excused absence granted by the school or the student's professor. Excused absences may be granted for five general reasons:

1. Student is unable to attend class due to unexpected and immediate physical or mental wellbeing concerns (illness, surgery, injury, mental health, or hospitalization). In this regard, the student is reasonably unable to attend class, or it is in the best interest of the student's health and/or the health of the Mines community for the student to be excused.
2. Student has a documented personal reason for the absence (e.g., jury duty, death in the immediate family, religious holiday or observance, etc.) or unforeseen, unavoidable, and anomalous conflict subject to review and approval.
3. Student is a sanctioned athlete and representing Mines in a sanctioned athletics activity per the Athletics Department.
4. Student is representing Mines in an authorized activity related to a club or academic endeavor such as: academic competitions, student professional society conferences, department-sponsored trip, authorized research opportunity or request, club sport competition, program-sponsored competitions, etc. Regularly scheduled and/or recurring commitments may not qualify.
5. Student is granted an excused absence through a sanctioned office because of protected, unexpected, sensitive, or time-sensitive circumstance(s). Sanctioned offices are Office for Institutional Equity (i.e., Title IX), SOS, DSS, Dean of Students Office/VPSA.

It is recognized that excused absences will occasionally occur, and faculty are expected to establish and clearly communicate the Excused Absence Policy and course-specific guidance or expectations in their course Syllabus.

Faculty may grant an excused absence for their own course upon request by a student.

Student requests for an excused absence does not guarantee approval. Students may be asked to provide documentation and the excused absence request is subject to approval by Student Life. Approval may consider all aspects of the request, including the duration of the request and nature of the request.

Opportunistic or habitual abuse of the excused absence policy violates the Mines Code of Conduct. Any patterns of absences that specifically result in missing exams/tests/quizzes may be investigated.

Once an Excused Absence is Granted:

The University expects each student to be responsible for learning material missed because of an excused absence.

If the student missed an in-class graded activity because of their excused absence, the faculty have the following options:

1. Require that the activity be made up within a reasonable time frame based on the situation as determined by the faculty member.
2. Require that an alternative activity be completed within a reasonable time frame based on the situation as determined by the faculty member.
    a. If it is deemed necessary by the faculty to use an alternative activity, it should be comparable in terms of rigor and time of completion to the original activity in such a way that having missed the original activity will not penalize the student.
    b. The alternative activity should also align with the same learning objectives as the original graded activity.
3. Remove the graded activity from the student's overall grade calculation: If the faculty determines certain graded activities have pedagogical value which cannot be reasonably replicated, they will instead remove those graded activities from the student's overall grade calculation.

    a. This will be separate from any grading adjustment(s) - including but not limited to dropping the lowest grade(s) - available to the rest of the class.

Any out-of-class graded activities that are due on the day of an excused absence may be accommodated. The details can be established by faculty based on the student situation or more generally in their course syllabus.

Excessive Absences

A student can jeopardize their opportunity to gain and demonstrate course mastery with excessive absences.

Further, a student can jeopardize their academic status with an unreasonable number of removed graded activities. If the number of removed graded activities (defined as #3 from "Once an Excused Absence is Granted") surpasses a reasonable threshold set by the faculty in the course Syllabus, then additional missed graded activities may not be removed, and the student may be advised to withdraw from the course or receive the subsequent and appropriate grade, which may include failure of the course.

Students should review the Incomplete and Complete Hardship or Medical Withdrawal Policies if they believe that these procedures may apply in their situation given excessive absences. Additional information on withdrawals can be found here and information on incompletes can be found here.

Any student with chronic absences may be required to meet with Student Life to discuss resources available to them to reduce future absences.

Unexcused Absences

All absences that are not documented as excused absences are considered unexcused absences. Faculty members may deny a student the opportunity to make up some or all work missed due to an unexcused absence(s). However, faculty members have discretion to grant a student permission to make up any missed academic work for an unexcused absence. The faculty member may consider the student's class performance and attendance in the decision.

Important Note: *Faculty will seek to honor all documented excused absences according to this policy and the course Syllabus. However, class attendance is essential to understand the material and for learning to take place. Excessive or opportunistic absences regardless of the reason may result in a reduced or failing grade in the course based on course content and delivery. As content and delivery differ among faculty and classes, it is important for a student missing class to discuss the absences, excused or unexcused, with his/her/their faculty member(s) to determine what will be considered excessive.*

Withdrawal from School

A student may officially withdraw from Mines – temporarily or permanently – by contacting the Dean of Students Office and completing the *Complete Withdrawal Request form*.

Complete withdrawal requests may be submitted until close of business on the last day of scheduled classes for the term (Review Day is not a scheduled class day), and will result in Ws assigned to all courses in progress.

Students may request a hardship withdrawal. Hardship withdrawals may include medical matters but will also more appropriately account for withdrawals associated with natural disasters, financial hardship, family priorities, or anomalous documented considerations (i.e., significant personal circumstances). Hardship withdrawals may be verified by corroborating documentation. Hardship withdrawals will not be considered as part of the Maximum Withdrawal Policy calculations.

Guaranteed re-entry to Mines for the term immediately following a complete withdrawal (standard withdrawal or hardship withdrawal) is only possible if a student completely withdraws by the course withdrawal deadline – approximately 13 weeks into the term (as noted on the Mines Academic Calendar).

If a student wishes to return to Mines for the immediate term following a complete withdrawal requested after the course withdrawal deadline (e.g., fall to spring, spring to summer, summer to fall), a student must submit a complete petition to the Dean of Students Office prior to the first scheduled class day of the immediate next academic term (noted as Class Start on the Mines Academic Calendar). Petition instructions and form are available via the Student Life website or Dean of Students Office.

A return petition will be reviewed by the Dean of Students Office (or designated representative). Approvals or denials of a student's petition may be decided by the dean of students. Students who wish to appeal a denial may do so with the VP of Student Life (or designated representative). Appeals are made by way of an email which asks for reconsideration of the denial and must be requested within five business days of the denial.

A return petition may necessitate appropriate documentation which clearly supports a student's intention to return. When relevant, Mines will engage the institution's chosen clinician (medical or mental health) to help evaluate the student's readiness to return, in consultation with the Dean of Students Office, including reviewing any non-Mines clinician documentation provided.

Failure to officially withdraw will result in the grades of courses as earned, which may include a notation of F. Leaving the school without having paid tuition and fees will result in a hold being placed against the transcript. Additionally, students may be sent to collections for failing to reconcile all outstanding debt to the institution. Either of these actions would make future enrollment at Mines or another college more difficult. Read more about withdrawing from Mines here.

Admissions Procedures

All Applicants

All admission decisions are final, with one exception. If your admission to the Colorado School of Mines is denied based on the information you provided regarding your criminal history, pending criminal charges, or disciplinary history at another academic institution, you have the right to an appeal. Appeals must be in writing and should be submitted to the associate provost for enrollment management at admissions@mines.edu within 14 days of receipt of the admissions decisions. Appeals should include all relevant information you would like the associate provost to consider. You will be notified of the outcome of your appeal within 14 days of receipt.

Please refer to our website for current undergraduate admissions policies, deadlines and processes.

Transfer of Credit by Review

Not all college courses taken at prior institutions are guaranteed to transfer. Requests for transfer credit are processed by the Registrar's Office. Credits must be submitted on an official transcript from a regionally accredited institution or if the institution is international, credit is only considered from institutions that are recognized by the Ministry of Education or other official accrediting or recognition body in the country of origin. See the International Student admissions webpage for additional details.

Visit the Registrar's Office transfer webpage for all current Transfer Articulation Agreements.

Advanced Placement, International Baccalaureate, A-Levels and concurrent Enrollment

Visit the Registrar's Office transfer webpage for all AP, IB, A-level and concurrent enrollment information.

Undergraduate Non-Degree Students

Our undergraduate non-degree option is designed for students who are interested in taking courses at Mines but do not plan on pursuing a degree at that time. Undergraduate non-degree applicants include individuals who have not completed a bachelor's degree or higher. Individuals who have already completed a bachelor's degree, master's degree, PhD or doctoral-level degree must submit a graduate non-degree application. Registration in the requested courses is based on availability (after all current students have registered for their courses), completion of the non-degree application, and proof of prerequisites through the submission of official transcripts and/or test scores. A non-degree student is one who has not applied to pursue a degree program at Mines but wishes to take courses regularly offered on campus. Non-degree students pay all applicable tuition and student fees. Non-degree students are not eligible for financial aid. Only 12 hours of non-degree-seeking courses may be applied toward a Mines degree. Applicants for admission to undergraduate programs who do not meet admissions requirements may not fulfill deficiencies as a non-degree student.

Returning Mines students

Colorado School of Mines welcomes any previous Mines student who left the University in good standing and wishes to resume their studies at Mines. Students must complete the returning student application and must provide official transcripts from other colleges and universities attended since last attending Mines.

If a student is required to see the Readmissions Committee before returning to Mines, the Undergraduate Admissions Office will not process the returning student application until a decision has been rendered and communicated from the Readmissions Committee. Readmission is granted at the discretion of the University. Factors that may be considered when determining eligibility for readmission include, but are not limited to, registration or transcript holds, previous academic achievement, length of absence, space availability, activities during the period of non-enrollment, and prior disciplinary action.

Health Requirements

Visit the Health Center website for current information on health requirements.

Combined Undergraduate/ Graduate Degree Programs

Combined Program Overview

Please refer to the Combined program section of the graduate portion of this catalog for more information about combined program requirements and considerations.

Learn more about combined program options, timelines and requirements.

Core Curriculum

The Purpose and Definition of the Core Curriculum

The core is the set of classes vertically aligned through four years required of all Mines students. Students complete courses in the core curriculum to develop and strengthen scientific and engineering knowledge, and to explore the contextualization of that knowledge in a sociotechnical, professional, and global community. In addition to foundational knowledge in math and science, the core curriculum also facilitates student success in crucial areas, including personal and professional development, understanding of global and societal contexts, ability to communicate effectively in a variety of settings, and capacity for critical and creative problem solving. To achieve these goals, the core content will be aligned with 26 core competencies. They are designed to advance the integration of pathways for the signature student experience in a way that is scaffolded from the core curriculum through to graduation.

The core curriculum as of academic year 23 - 24 builds on existing strengths within the curriculum, while also providing an expanded range of opportunities for integrative, exploratory, experiential, interdisciplinary, and enhanced hands-on learning. It includes a greater focus on student wellness, with a process for recognizing the importance of activities that facilitate personal growth and encourage a balanced and healthy campus lifestyle. Continuing students should refer to the Appendix section (p. 23) at the bottom of this page to understand updates and review guidelines for degree completion.

The courses in the core curriculum are organized in the following topical areas:

1. Math, Basic Sciences, & Computing
2. Design and Innovation
3. Culture and Society (CAS)
4. Success and Wellness (S&W)
5. Student-Led Inquiry

All students are required to complete the following core course requirements, and they are strongly encouraged to do so in accordance with the schedule outlined by your degree program. Failure to do so may delay a student's ability to graduate. Students should check out Degree Works to verify requirements for your program.

Table 1: List of Core Course Requirements

In Math, Basic Sciences, and Computing		
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0
MATHXXX	Fourth MATH course as specified by degree	3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	4.0
PHGN100	PHYSICS I - MECHANICS	4.0
CSCI128	COMPUTER SCIENCE FOR STEM	3.0
In Design and Innovation		
EDNS151	CORNERSTONE - DESIGN I	3.0
Culture and Society		
HASS100	NATURE AND HUMAN VALUES	3.0
HASS200	GLOBAL STUDIES	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
CAS Elective	Two mid-level courses from the approved list	6.0
CAS Elective	One 400-level course from the approved list	3.0
In Success and Wellness		
CSM101	FRESHMAN SUCCESS SEMINAR	1.0

CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES	1.0
CSMXXX	One course from the approved list	1.0
In Student-Led Inquiry		
Free Electives	6 credits	6.0
Total Semester Hrs		**56.0**

Math, Basic Sciences, & Computing

Courses in this category offer a scientific and technical foundation that prepares students for advanced coursework in their disciplines.

Table 2: Cluster of Courses in Math, Basic Sciences, and Computing

MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0
MATHXXX	Fourth MATH course as specified by degree	3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	4.0
PHGN100	PHYSICS I - MECHANICS	4.0
CSCI128	COMPUTER SCIENCE FOR STEM	3.0
Total Semester Hrs		**26.0**

MATH XXX refers to MATH 201, MATH 225, or MATH 332. Students should check out Degree Works to verify MATH requirements for your program.

Design and Innovation

Design and Innovation immerses students in hands-on, iterative, project-based inquiry. Cornerstone Design combines engineering design, design thinking, entrepreneurial thinking, and systems analysis to pursue open-ended problem scoping, definition and articulation. Students learn fundamental STEM analysis, design tools, business acumen and professional communication skills necessary for academic and professional success.

Table 3: Course in Design and Innovation

EDNS151	CORNERSTONE - DESIGN I	3.0
Total Semester Hrs		**3.0**

Culture and Society (CAS)

Culture and Society (CAS) courses provide cultural and social perspectives to advance students' understanding of the contemporary, global world. These courses help students contextualize scientific and technical knowledge and practice to better understand their potential impacts on people, organizations, the economy and the environment. CAS courses also enhance students' abilities to communicate, explore diverse perspectives, and grapple with ethics and professional responsibilities. Ultimately, these courses provide the opportunity for students to explore what it means to be human in an interconnected world.

Table 4: Cluster of Courses in CAS

HASS100	NATURE AND HUMAN VALUES	3.0
HASS200	GLOBAL STUDIES	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
Mid-Level CAS Electives		6.0
Senior CAS Elective		3.0
Total Semester Hrs		**18.0**

The 9 credits of mid-level and 400-level CAS electives must meet the following requirements:

- At least 3 credits must be at the 400 level.
- At least 3 credits must have a HASS course code.
- No more than 6 credits can have the LIFL (Foreign Languages) course code.
- Courses with the LIMU (Music) course code cannot be used to satisfy this requirement.
- HASS498 special topic courses can be used to satisfy this requirement.#EBGN498 andEDNS498 special topic courses will be determined to satisfy this requirement on a course-by-course basis, and that determination will be made prior to the beginning of the term the course is offered.
- Except for foreign languages, no AP or IB credit can be used to meet this requirement. (AP/IB credits will be applied as free electives.)
- Single majors in Economics cannot use courses with the EBGN course code to satisfy this requirement.

Table 5 (p.) includes the complete list of courses satisfying the CAS requirement.

Table 5: List of CAS Electives

HASSXXX	All courses with the HASS prefix are eligible for CAS credit	
LIFLXXX	All LIFL courses are eligible for CAS (midlevel) credit	
HNRSXXX	All HNRS courses are eligible for CAS credit (see your advisor)	
Economics and Business Courses approved for CAS credit		
EBGN201	PRINCIPLES OF ECONOMICS	3.0

EBGN301	INTERMEDIATE MICROECONOMICS	3.0
EBGN302	INTERMEDIATE MACROECONOMICS	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
EBGN320	ECONOMICS AND TECHNOLOGY	3.0
EBGN330	ENERGY ECONOMICS	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
EBGN430	ADVANCED ENERGY ECONOMICS	3.0
EBGN434	PROPERTY RIGHTS AND NATURAL RESOURCES	3.0
EBGN437	REGIONAL ECONOMICS	3.0
EBGN441	INTERNATIONAL ECONOMICS	3.0
EBGN443	PUBLIC ECONOMICS	3.0
EBGN470	ENVIRONMENTAL ECONOMICS	3.0
Engineering, Design, and Society courses approved for CAS credit		
EDNS315	ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY	3.0
EDNS477	ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT	3.0
EDNS478	ENGINEERING AND SOCIAL JUSTICE	3.0
EDNS479	COMMUNITY-BASED RESEARCH	3.0
EDNS480	ANTHROPOLOGY OF DEVELOPMENT	3.0
Other courses approved for CAS credit		
MNGN335	COMMUNITIES AND NATURAL RESOURCE DEVELOPMENT	3.0
PEGN430	ENVIRONMENTAL LAW AND SUSTAINABILITY	3.0

Success and Wellness (S&W)

Success and Wellness (S&W) courses facilitate personal growth and encourage a balanced and healthy campus lifestyle. S&W courses are applied, experiential courses that impart foundational practical, lifelong skills or competencies to the benefit of a student's future scholastic efforts and/or personal and professional aspirations.

Table 6: Cluster of Courses in S&W

CSM101	FRESHMAN SUCCESS SEMINAR	1.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES	1.0
S&W Electives		1.0
Total Semester Hrs		**3.0**

The table below includes the complete list of courses satisfying the S&W Requirements:

Table 7: List of S&W Electives

CSM102	INTRODUCTION TO TECHNICAL WRITING	1.0
CSM250	ENGINEERING YOUR CAREER PATH	1.0
CSM275	CASA BOUNCE BACK PROGRAM	1.0
CSM350	STUDIES IN LEADERSHIP	3.0
CSM301	INTRODUCTION TO PUBLIC SPEAKING & COMMUNICATION SKILLS	1.0
PAGN2XX	Any 1.0 credit PAGN2XX	1.0

Student-Led Inquiry

Through this category, students will have a mechanism to pursue minors and/or additional academic course work that appeals to their interests and passion. All students regardless of the major can take 6 credits of free electives.

Appendix: Revised Core for 23-24 and Beyond

The Board of Trustees of the Colorado School of Mines reserves the right to change any course of study or any part of the curriculum in keeping with educational and scientific developments; nothing in this catalog or the registration of any student shall be considered as a contract between Colorado School of Mines and the student.

In accordance with the statement on Curriculum Change (above), the Colorado School of Mines is entering a process of core curriculum revision. The table below shows the effects of the revision to the core launched in 23 – 24. The core curriculum may see further revisions in future catalog years after the new core goes through an assessment cycle of measuring how well the competencies are being met, and to meet any future needs to keep the curriculum relevant. To confirm that they are progressing according to the requirements of the revised curriculum, students should consult their CASA academic advisor and/or departmental faculty mentor on a regular basis and should carefully consult anyCatalog Addendathat may be published during this period.

Old Core and Credit Hour (CH) Changes

- PHGN100 Credit Hour change from 4.5 to 4
- HASS Credit Hour change from 4 to 3

- Addition of CSM202 at 1 Credit Hour
- Addition of CSCI128 at 3 Credit Hours
- Free Elective minimum Credit Hours reduced from 9 to 6
- All PAGN courses Credit Hour change from .5 to 1
- CSM 101 Credit Hour change from .5 to 1

Table 8: New Core

MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0
MATHXXX	Fourth MATH course as specified by degree	3.0
EDNS151	CORNERSTONE - DESIGN I	3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	4.0
PHGN100	PHYSICS I - MECHANICS	4.0
CSCI128	COMPUTER SCIENCE FOR STEM	3.0
HASS100	NATURE AND HUMAN VALUES	3.0
HASS200	GLOBAL STUDIES	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
CAS Elective		9.0
CSM101	FRESHMAN SUCCESS SEMINAR	1.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES	1.0
S&W Electives		1.0
Free Electives		6.0
Total Semester Hrs		**56.0**

Guidelines for Incoming Students

All students are required to complete all core requirements and are strongly encouraged to do so in accordance with the schedule outlined by your degree program. Failure to do so may delay a student's ability to graduate. Students are encouraged to consult Degree Works to verify requirements for your program.

All first year incoming students will be required to complete the core requirements as outlined in Table 1: List of Core Course Requirements. Flexibility may be needed in when students are able to take CSCI128 and CSM202.

Guidelines for Continuing Students

Students who have already completed one or more semesters at Mines should consult with their academic advisors or departmental faculty mentors to determine if they would like to switch to a newer catalog. The following set of guidelines should be able to help students have these conversations and make informed decisions.

Continuing Students Switching to New Catalog

Students choosing to switch catalog may have completed courses at an older CH requirement. Example, HASS100 used to be a 4 CH course but is a 3 CH course starting 23 – 24. Similarly, PHGN100 is down from 4.5 to 4 CH . Students who have completed courses per the older catalog requirements and are switching catalogs can substitute older courses for revised courses in the new catalog. They do not need to retake these courses. Students will complete any of the remaining coursework for graduation per the revised CH in the new catalog.

- Students who have already completed CSCI101 at 3 CH or CSCI101 and CSCI102 for a total of 4 CH can substitute it for CSCI128 should they choose to switch catalogs.
- Students who have taken CSM101at 0.5 CH will not need to retake the course. If students have taken three or more PAGN credits at 0.5 CH already, they are not required to take CSM202.
- Students who have completed EBGN201 and want to switch to a newer catalog will still need to complete EBGN321. EBGN201 can be considered mid-level CAS elective or a free elective.
- Figure 1 and Figure 2 summarize how students who choose to switch catalogs can complete their core requirements without having to take additional or repeating coursework. The sections on Completing Core CS requirements, Completing CAS requirements, and Completing Core S&W Requirements outline the options in more detail.

Continuing Students Staying on Old Catalog

For students completing degree requirements under a catalog prior to 2023-2024, the credits of some courses may have decreased. For example, HASS 100 (4 to 3 CH) and PHYS 100 (4.5 to 4 CH). The new versions of those updated courses will still fulfill the previous course requirements, but students may need to enroll in additional elective credits to meet the minimum overall Credit Hours needed to complete their degree.

Please refer to Figure 3: Expectations from students who do not switch catalogs to check how to complete CS requirements.

Continuing students who remain on the old catalog may need to complete one or two CH of Success and Wellness Electives to complete the PAGN requirements per the old catalog. Refer to Figure 4: Expectations from students who do not switch catalogs but still need to complete their PAGN requirements.

Guidelines for Students bringing External Credit

Please refer to the transfer information on the registrar's website for the most current requirements.

Completing Core CS Requirements

1. If a student is on an existing catalog that requires 101 and they have taken it, then their options are:
    a. Do nothing, remain on the old catalog
    b. Change to newer catalog (AY 23-24 or after) and have CSCI101 substitute for CSCI128

2. If a student is on an existing catalog that requires 101 but they haven't taken it yet, then their options are:
   a. Remain on the old catalog and take CSCI128 in Fall 2023 or later and have CSCI128 substitute for CSCI101
   b. Change to newer catalog (AY 23-24 or after) and take CSCI128 in Fall 2023 or later
3. If a student is on an existing catalog that does not require CSCI101 and they have taken it, then their options are:
   a. Do nothing, remain on the old catalog
   b. Change to newer catalog (AY 23-24 or after) and have CSCI101 substitute for CSCI128
4. If a student is on an existing catalog that does not require CSCI101 and they have not taken it, then their options are:
   a. Do nothing, remain on the old catalog
   b. Change to newer catalog (AY 23-24 or after) and#take CSCI128 in Fall 2023 or later

Completing CAS Requirements

1. If a student is on an existing catalog that requires EBGN 201 and they have taken it, then their options are:
   a. Do nothing, remain on the old catalog (catalog prior to 23 – 24)
   b. Change to newer catalog (AY 23 – 24 or after)
      i. Complete EBGN 321
      ii. Have EBGN 201 count as a mid-level CAS elective or free elective

Completing Core S&W Requirements

1. If a student is currently on a catalog prior to 23 – 24, their options are:

a. Remain on the old catalog.

i. Complete CSM101, if not already.

ii. Complete at least 2.0 CH of (old catalog) PAGN requirement (if not met and previously earned via 4 PAGN courses) by way of CSM102 (1CH), CSM250 (1CH), CSM202 (1CH), CSM275 (1CH), CSM301 (1 CH), CSM350 (3CH), or PAGN2XX (1CH).

b. Change to newer catalog (AY 23-24 or after)

i. Complete CSM101, if not already.

ii. If a student has earned 0.5 CH or 1 CH of PAGN credit prior to switching to a newer catalog (AY 23 – 24 or after), then

A. Complete CSM202

B. Complete at least 1.0 CH S&W requirement by way of CSM102 (1CH), CSM250 (1CH), CSM275 (1CH), CSM301 (1 CH), CSM350 (3CH), PAGN2XX (1CH).

iii. If a student has earned 1.5 CH or 2 CH of PAGN credit prior to switching to a newer catalog (AY 23 – 24 or after), then no further action needed. *NOTE: This accepts the potential of only 2 or 2.5 credits earned (because CSM101 prior to Fall 23 was 0.5 CH). This is permissible.*

General Information

Academic Calendar

The academic year is based on the early semester system. The first semester begins in late August and closes in mid-December; the second semester begins in early January and closes in mid-May.

Classification of Students

Degree seeking undergraduates are classified as follows according to semester credit hours earned:

Undergraduate Year	Semester Credit Hours Earned
Freshman	0 to 29.9 semester credit hours
Sophomore	30 to 59.9 semester credit hours
Junior	60 to 89.9 semester credit hours
Senior	90 or more semester credit hours

Course Numbering & Subject Codes

Numbering of Courses

Course numbering is based on the content of material presented in courses:

Material	Level	Division
100-199	Freshman Level	Lower Division
200-299	Sophomore Level	Lower Division
300-399	Junior Level	Upper Division
400-499	Senior Level	Upper Division
500-599	Graduate Level	
600-699	Advanced Graduate Level	
Over 700	Graduate Research or Thesis Level	

Subject Codes:

Course Code	Course Title
AFGN	Air Force
AMFG	Advanced Manufacturing
BIOL	Biology
CBEN	Chemical & Biological Engineering
CEEN	Civil & Environmental Engineering
CHGC	Geochemistry
CHGN	Chemistry
CSCI	Computer Science
CSM	General Studies; Skills Courses
DSCI	Data Science
DTCN	Data Center Engineering
EBGN	Economics & Business
EDNS	Engineering, Design, and Society
EENG	Electrical Engineering
ENGY	Energy
FEGN	Finite Element Analysis
GEGN	Geological Engineering

GEGX	Geochemical Exploration (Geology)
GEOC	Oceanography (Geology)
GEOL	Geology
GOGN	Geo-Engineering (Mining)
GPGN	Geophysical Engineering
HASS	Humanities, Arts, and Social Sciences
HNRS	Honors Program
LICM	Communication
LIFL	Foreign Languages
LIMU	Music; Band; Choir
MATH	Mathematics
MEGN	Mechanical Engineering
MLGN	Materials Science
MNGN	Mining Engineering
MSGN	Military Science
MTGN	Metallurgical & Materials Engineering
NUGN	Nuclear Engineering
ORWE	Operations Research with Engineering
PAGN	Physical Education & Athletics
PEGN	Petroleum Engineering
PHGN	Physics
ROBO	Robotics
SPRS	Space Resources
SYGN	Core Sequence in Systems

Curriculum Changes

In accordance with the statement on Curriculum Changes, the Colorado School of Mines makes improvements in its curriculum from time to time. To confirm that they are progressing according to the requirements of the curriculum, students should consult their academic advisors on a regular basis, reference the online degree evaluation, and carefully consult any Catalog Addenda that may be published.

Part-Time Degree Students

A part-time degree student may enroll in any course for which he or she has the prerequisites or the permission of the department. Part-time degree students will be subject to all rules and regulations of Colorado School of Mines, but they may not:

1. Live in student housing;
2. Receive financial help in the form of school-sponsored scholarships or grants;
3. Participate in any school-recognized activity unless fees are paid;
4. Take advantage of activities provided by student fees unless such fees are paid.

Coursework completed by a part-time degree student who subsequently changes to full-time status will be accepted as meeting degree requirements.

Seniors in Graduate Courses

With the consent of the student's department/division and the dean of graduate studies, a qualified senior may enroll in 500-level courses without being a registered graduate student. At least a 2.5 GPA is required. Any undergraduate taking graduate-level credit must receive approval and agree to the specific terms selected.

- Students requesting the credits as undergraduate credits or those who do not qualify to have the credits listed on the graduate transcript must register for the course as UG (undergraduate credit). The credits will be listed on the undergraduate transcript and the credits will impact the undergraduate GPA.
- Students who request the credits as graduate-level credits and meet the qualifications to have the credits listed on the graduate transcript must register for the course as GR (graduate credit). The credits will be listed on the graduate transcript and the credits will impact the graduate level GPA.
- Once registered as UG or GR, the level cannot be changed after Census Day of the semester in which the course is taken.
- Students may apply up to 12 credits of unused graduate-level coursework, registered as GR, while enrolled as a full-time undergraduate student, toward a Mines graduate degree. For students in a combined program, these credits are in addition to the 6 credits being counted toward both the undergraduate and graduate degrees as double counted courses.
- Financial aid may be impacted. Email finaid@mines.edu for more information on financial aid impacts.

Course Substitution

To substitute credit for one course in place of another course required as part of the approved curricula in the catalog, a student must receive the approval of the registrar, the heads of departments of the two courses, the head of the student's option department. There will be a periodic review by the Office of the Executive Vice President for Academic Affairs. Forms for this purpose are available in the Registrar's Office.

Change of Catalog

It is assumed that each student will graduate under the requirements of the catalog in effect at the time of most recent admission. However, it is possible to change to any subsequent catalog in effect while the student is enrolled in a regular semester.

To change catalogs, a form obtained from the Registrar's Office is presented for approval to the head of the student's option department. Upon receipt of approval, the form must be returned to the Registrar's Office.

Students' Use of English

All Mines students are expected to show professional facility in the use of the English language.

English skills are emphasized, but not taught exclusively, in most of the Culture and Society (CAS) courses and EPICS as well as in option courses in junior and senior years. Students are required to write reports, make oral presentations, and generally demonstrate their facility in the English language while enrolled in their courses.

The Writing Center is available to assist students with their writing. For additional information, contact Allyce Horan, director of the Writing Center at 303-384-2265.

Summer Sessions

The summer term is divided into two independent units. Summer Session I is a six-week period beginning on Monday following spring

Commencement. Summer Session II is either a six-week or eight-week session which immediately follows Summer Session I.

Review Day

No required class meetings, examinations or activities may take place on the Friday immediately preceding final exams for the fall and spring terms. At their own discretion, faculty members may hold additional office hours or give a review session on Review Day provided these activities are strictly optional. This day has been created as a break from regularly scheduled and/or required academic activities to allow students to prepare for their final examinations as they see fit.

Common Examinations Policy

At the time of publication the Common Exam Policy was under revision.

Please see the Catalog Addendum.
https://www.mines.edu/registrar/program-changes/

Final Examinations Policy

Final examinations are scheduled by the registrar. With the exception of courses requiring a common time, all finals will be scheduled on the basis of the day and the hour the course is offered.

In general, all final examinations will be given only during the stated final examination period and are to appear on the registrar's schedule. Faculty policy adopted in January 1976 provides that no exams (final or otherwise) may be scheduled during the week preceding final examinations week, with the possible exception of laboratory exams. The scheduling by an individual faculty member of a final exam during the week preceding final examinations week is to be avoided because it tends to hinder the students' timely completion of other coursework and interfere with the schedules of other instructors. Faculty members should not override this policy, even if the students in the class vote to do so.

Students who have conflicts with the final exam schedule or have more than two exams on the same day should inform their instructors. The instructor of the highest numbered course is required to grant relief (e.g., an alternate time during exam week).

Academic activities that are explicitly disallowed by this policy include:

• Scheduling an in-class examination (final or otherwise, with the possible exception of laboratory exams) for any course during the week preceding final exams

• Scheduling an early make-up final examination, unless the student needs to miss the regularly scheduled final for school-related business (athletics, school-related travel, etc.) and requested by the student and approved by the instructor.

• Assigning a take-home final examination for any course that is due during the week preceding final exams, unless the student needs to miss the regularly scheduled final for school-related business (athletics, school-related travel, etc.) and requested by the student and approved by the instructor.

Academic activities that are allowable during the week preceding final exams include:

- The introduction of new materials
- Laboratory finals
- Required homework
- Required in-class assignments such as quizzes or worksheets (NO EXAMS)
  - Quizzes are shorter exercises which take place on a fairly regular basis (e.g., 15–30 minutes in duration, 6–10 times a semester).
  - Exams are major exercises which take place only a few times a semester (e.g., 50–120 minutes in duration, 2–4 times a semester).
- Major course assignments such as final presentations or term projects provided the assignment was assigned at least four weeks in advance or was clearly indicated in the course syllabus (Presentations must not be scheduled in conflict with regularly scheduled courses in departments outside of the one scheduling the presentation.)
- Take-home finals (provided they are not due prior to finals week)
- Make-up exams for students who miss a scheduled exam in the prior week due to emergency, illness, athletic event, or other CSM-sanctioned activity (provided this absence has been approved by the Dean of Students Office)

(Note: These policies apply only to undergraduate courses. Students enrolled in graduate courses, are bound by policies outlined in the Graduate Catalogs.)

Full-time Enrollment

Full-time enrollment for certification for veterans benefits, athletics, loans, most financial aid, etc., is 12 credit hours per semester for the fall and spring semesters. Full-time enrollment for Summer Session I and Summer Session II combined is 12 credit hours.

Good Standing, Honor Roll and Dean's List, Graduation Awards, Probation and Suspension

Good Standing

A student is in good standing at CSM when he or she is enrolled in class(es) and is not on either academic or disciplinary probation, suspension, or dismissal.

Honor Roll and Dean's List

To be placed on the academic honor roll, a student must complete at least 14 semester hours with a 3.0-3.499 grade-point average for the semester, have no grade below C, and no incomplete grade. Those students satisfying the above criteria with a semester grade-point average of 3.5 or above are placed on the Dean's List.

Students are notified by the dean of students of the receipt of these honors. The Dean's List notation appears on the student's transcript.

Graduation Awards

Colorado School of Mines awards the designations of cum laude, magna cum laude, and summa cum laude upon graduation. These designations are based on the following overall grade-point averages:

Grade-point average	Designation
3.500 - 3.699	Cum Laude
3.700 - 3.899	Magna Cum Laude
3.900 - 4.000	Summa Cum Laude

Commencement ceremony awards are determined by the student's cumulative academic record at the end of the preceding semester. For example, the overall grade-point average earned at the end of the fall term determines the honor listed in the May commencement program.

Final honors designations are determined once final grades have been awarded for the term of graduation. The final honors designation appears on the official transcript and is inscribed on the metal diploma. Official transcripts are available approximately one to two weeks after the term grades have been finalized. Metal diplomas are sent to the student approximately two months after final grades are posted. Mailing arrangements are made during Graduation Salute.

Undergraduate students are provided one metal diploma at no cost. Additional metal diplomas and parchment diplomas can be ordered online at the Registrar's Office webpage for an additional charge. Graduating students should order these items before the end of the graduation term in order to ensure delivery approximately two months after final grades are awarded.

Academic Probation & Suspension

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Academic standing is processed at the end of the fall, spring,
 and summer (if applicable) terms.
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Probation

A student whose cumulative grade-point average falls below the minimum requirement of 2.0 will be placed on academic probation for the following semester. A student on probation is subject to the following restrictions:

1. The student may not register for more than 15 credit hours.
2. The student may be required to withdraw from intercollegiate athletics.
3. The student may not run for, or accept appointment to, any campus office or committee chairmanship. A student who is placed on probation while holding a position involving significant responsibility and commitment may be required to resign after consultation with the Dean of Students Office or the president of Associated Students. A student will be removed from probation when the cumulative grade-point average is brought up to the minimum, as specified in the table below.

Suspension

A student whose cumulative grade-point average falls below the minimum requirement of 2.0 will be placed on academic probation for the following semester (fall, spring, or summer). A student who satisfies the current term grade period requirement but fails to achieve the required cumulative grade-point average will remain on probation. A student who fails to earn above a 2.0 GPA (current term and cumulative) while on probation will be suspended.

A first-year or transfer student who fails to make a grade-point average of 2.0 in the first grade period will be on academic probation for the following academic term. Additionally, the student will be required to meet with the Center for Academic Services and Advising (CASA) for counsel. Students may not continue their studies until meeting with CASA.

Suspension becomes effective immediately when it is imposed. Readmission after suspension requires written approval from the Readmissions Committee.

No student who is suspended may enroll in any regular academic semester without the written approval of the Readmissions Committee. However, a student on suspension may enroll in a summer session (field camp, academic session, or both) with the written permission of the Dean of Students Office. Students on suspension who have been given written permission to enroll in a summer session course(s) by the dean may not enroll in any subsequent term at CSM without the written permission of the Readmissions Committee. Students who are suspended may not register for a period of at least one term (fall or spring).

A student who intends to appear in person before the Readmissions Committee must contact the Dean of Students Office at least one week prior to the desired appointment. Between regular meetings of the committee, in cases where extensive travel would be required to appear in person, a student may petition in writing to the committee, through the Dean of Students Office. Appearing before the Readmissions Committee virtually or by letter rather than in person will be permitted only in cases of extreme hardship or insurmountable circumstances. Such cases will include travel from a great distance, e.g., overseas, or travel from a distance which requires leaving a permanent job.

The Readmissions Committee meets on six separate occasions throughout the year. Students applying for readmission must appear at those times except under conditions beyond the control of the student. Such conditions include a committee appointment load, delay in producing notice of suspension, or weather conditions closing highways and airports.

All applications for readmission must include a written statement of the case to be made for readmission.

A student who, after being suspended and readmitted twice, again fails to meet the academic standards shall be academic dismissed. The Readmissions Committee will hear a single appeal of automatic dismissal. The appeal will only be heard after demonstration of substantial and significant changes. A period of time sufficient (i.e., one calendar year) to demonstrate such a change usually elapses prior to the student attempting to schedule this hearing. The decision of the committee on that single appeal will be final and no further appeal will be permitted.

Readmission by the committee does not guarantee that there is space available to enroll. A student must process the necessary papers with the Admissions Office prior to seeing the committee.

Notification

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Academic standing is processed at the end of the fall, spring,
 and summer (if applicable) terms. Notice of probation,
 suspension, or dismissal will be mailed or emailed to each
 student who fails to meet catalog requirements.
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Repeated Failure

A student who twice fails a required course at Colorado School of Mines and is not subject to academic suspension will automatically be placed on "special hold" status with the registrar, regardless of the student's cumulative or semester GPA. The student must meet with the subject advisor and receive written permission to remove the hold before being allowed to register.

In the case of three or more Fs in the same course, the student must meet with the faculty Readmissions Committee and receive permission to remove the hold before being allowed to register.

Transfer credit from another school will not be accepted for a twice-failed course.

Multiple Withdrawal Policy

The total number of withdrawn course credits (e.g., courses resulting in a W grade) over a student's academic career are tracked and counted at the end of each academic semester (fall and spring terms). When the following credit limits have been met or surpassed, the associated academic standing provisions will result.

When a student has accumulated 20 or more withdrawn credits, the student will receive support including possible admission to the Bounce Back program and individual academic coaching and assistance.

When a student has accumulated 30 or more withdrawn credits, the student will receive a first (or greater) suspension for failing to meet academic performance standards. The student must meet with the Readmissions Committee and secure a majority vote in favor of their return.

When a student has accumulated 45 or more withdrawn credits, the student will receive a second (or greater) suspension for failing to meet academic performance standards. To return, the student must meet with the Readmissions Committee and secure a majority vote in favor of their return.

When a student has accumulated 60 or more withdrawn credits, the student will receive a third suspension resulting in dismissal or terminal dismissal for failing to meet academic performance standards.

Withdrawn credits resulting from a hardship or medical withdrawal will not count toward the total number of withdrawn credits for the purposes of this policy.

For further information, please contact the Dean of Students Office.

Grading System, Grade-Point Average (GPA), and Grade Appeals

Undergraduate grading system

Grades

When a student registers in a course, one of the following grades will appear on his/her academic record. If a student registered as NC (audit) fails to satisfy all conditions, no record of his registration in the course will be made. The assignment of the grade symbol is based on the level of performance and represents the extent of the student's demonstrated mastery of the material listed in the course outline and achievement of the stated course objectives.

Symbol	Interpretation
A	Excellent
A-	
B+	
B	Good
B-	
C+	
C	Satisfactory
C-	
D+	
D	
D-	Poor (lowest passing)
F	Failed
S	Satisfactory, C or better, used at mid-term
U	Unsatisfactory, below C, used at mid-term
PRG	Satisfactory Progress
PRU	Unsatisfactory Progress

In addition to these performance symbols, the following is a list of registration symbols that may appear on a Mines transcript:

Symbol	Interpretation
WI	Involuntary Withdrawal
W	Withdrew, no penalty
T	Transfer Credit
INC	Incomplete
NC	Not for Credit (Audit)
Z	Grade not yet submitted

Incomplete Grade

An Incomplete (INC) is a temporary grade which may be given at the instructor's discretion to a student when illness, necessary absence, or other reasons beyond the control of the student prevent completion of course requirements by the end of the academic term. An INC is restricted to cases in which the student satisfactorily completed a significant amount of the coursework, including attendance and participation.

The student and the instructor should discuss the terms for the incomplete before the end of the term. The instructor may grant up to one year, but the time limit may be less, to complete outstanding coursework. Any outstanding grade of INC will be converted to an F grade if it has not been updated by the instructor after one year. In the event that an INC grade remains on the record at the completion of the degree, the INC will be converted to an F and included in the final GPA.

NC Grade (Not for Credit or Audit)

A student may, for special reasons and with the instructor's permission, register in a course on the basis of NC (Not for Credit). To have the grade NC appear on his/her transcript, the student must enroll at registration time as an NC student in the course and comply with all conditions stipulated by the course instructor; however, if a student registered as NC fails to satisfy all conditions, no record of this registration in the course will be made. The Registration Action form is used to request that a course be recorded as an audit. The form is available in the Registrar's Office.

Transfer Credit

Transfer credit earned at another institution will have a T grade assigned, but no grade points will be recorded on the student's permanent record. Calculation of the grade-point average will be made only from the courses completed at Colorado School of Mines.

GPA Hours and Quality Points

For graduation, a student must successfully complete a certain number of required credits and must maintain grades at a satisfactory level. The system for expressing the quality of a student's work is based on quality points and GPA hours. The numerical value associated with the specific grades are:

Grade	Numerical Value
A	4.000
A-	3.700
B+	3.300
B	3.000
B-	2.700
C+	2.300
C	2.000
C-	1.700
D+	1.300
D	1.000
D-	0.700
F	0.000

The number of quality points earned in any course is the number of credits assigned to that course multiplied by the numerical value of the grade received. To compute an overall or major grade-point average, the number of cumulative GPA hours is divided into the cumulative quality points received. Grades of W, WI, INC, PRG, PRU, or NC are not counted in quality hours.

Midterm Grading

Midterm grading is conducted using Satisfactory (S) and Unsatisfactory (U) grades. Certain foundational courses are required to be graded between the sixth and eighth weeks of the term to provide students an early warning with time to recover. If the midterm grade is blank in these specific courses, the grade for the student is Satisfactory (S) by default, or C- or better. Faculty will enter Unsatisfactory (U) grades for those students currently earning grades of D+ or lower.

Courses include: All core curriculum and Distributed Science Elective courses with the exception of CAS Mid-Level Cluster and 400-Level. Additionally, the following courses will also be included: CEEN241 (Statics), CEEN311 (Mechanics of Materials), MEGN261 (Thermodynamics 1), CSCI261 (Programming Concepts), CHGN209 (Chemical Thermodynamics), and CBEN210 (Intro to Thermodynamics) as they are key prerequisite courses for many students.

Credits

The number of times a class meets during a week (for lecture, recitation, or laboratory) determines the number of credits assigned to that course. Class sessions are normally 50 minutes long and represent one hour of credit for each hour meeting. A minimum of three hours of laboratory work per week are equivalent to 1-semester hour of credit. For the average student, each hour of lecture and recitation requires at least two hours of preparation. No full-time undergraduate student may enroll for more than 19 credits in one semester. Physical education, advanced ROTC and Honors Program in Public Affairs courses are excepted. However, upon written recommendation of the faculty advisor, the better students may be given permission by the registrar on behalf of Academic Affairs to take additional hours.

Grade-Point Averages

Grade-point averages shall be specified, recorded, reported, and used to three figures following the decimal point for any and all purposes to which said averages may apply.

Overall Grade-Point Average

If a course completed during the fall 2007 term through summer 2011 was a repeat of a course completed in any previous term and the course was not repeatable for credit, the grade and credits earned for the most recent occurrence of the course will count toward the student's grade-point average and the student's degree requirements. The most recent course occurrence must be an exact match to the previous course completed (subject and number). The most recent grade is applied to the overall grade-point average even if the previous grade is higher.

Only courses originally completed and subsequently repeated at Colorado School of Mines during fall 2007 through summer 2011 with the same subject code and number apply to this repeat policy.

Option (Major) Grade-Point Average

The grade-point average calculated for the option (major) is calculated in the same manner as the overall grade-point average. Starting fall 2011 the repeat policy is no longer in effect, and all attempts at major courses completed in the major department are included. However, the major grade-point average includes only the most recent attempt of a repeated course if the most recent attempt of that course occurs from fall 2007 through summer 2011.

The major grade-point average includes up to five ranges of courses within the department (e.g., SUBJ200-499) but not necessarily all courses (i.e., SUBJ 100-599Z), plus up to 10 single courses with different subject codes from outside of the department.

The minimum major grade-point average required to earn a Mines undergraduate degree is a 2.0. For specifics concerning major GPA, reference the department specific section of the catalog. Courses that comprise the major GPA are listed at the end of the degree requirement tables.

GPA Recovery Policy

All attempts at every Mines course will count in the overall grade-point average unless the student qualifies for GPA recovery. GPA recovery will only be possible if the most recent course grade was a D or an F (including plus and/or minus). As grades C or better are satisfactory from a degree attainment perspective, such grades do not qualify for GPA replacement. No classes taken before fall 2020 qualify for GPA Recovery.

If the student takes the course for a second time or third time, the most recent grade will be the only grade used to calculate the grade-point average (even if the previous grade(s) was higher). There will be no option to repeat for GPA recovery beyond a third attempt (i.e., third and/or greater attempts all count toward the GPA). All records of grades earned, including those excluded from GPA calculations as well as attempts (i.e. Ws) will be recorded on the student’s transcript. All withdrawals are still subject to the maximum withdrawal policy.

Courses from other institutions transferred to Colorado School of Mines are not counted in any grade-point average and cannot be used under this repeat policy.

Grade Changes

After the completion of final grading for a term, only corrections to errors in grading may be processed and they must be for grade improvements only. Corrections to errors in grading for all students will be accepted one year from the original grade entry. With the exception of punitive disciplinary actions, diminution of a grade is not allowed without approval of the provost.

Grade Appeal Process

Mines faculty have the responsibility, and sole authority for, assigning grades. As instructors, this responsibility includes clearly stating the instructional objectives of a course, defining how grades will be assigned in a way that is consistent with these objectives, and then assigning grades. It is the student's responsibility to understand the grading criteria and then maintain the standards of academic performance established for each course in which he or she is enrolled.

If a student believes he or she has been unfairly graded, the student may appeal this decision first to the instructor of the course, and if the appeal is denied, to the Academic Standards Committee of the Faculty Senate. The Academic Standards Committee is the faculty body authorized to review and modify course grades, in appropriate circumstances. Any decision made by the Academic Standards Committee is final. In evaluating a grade appeal, the Academic Standards Committee will place the burden of proof on the student. For a grade to be revised by the Academic Standards Committee, the student must demonstrate that the grading decision was unfair by documenting that one or more of the following conditions applied:

1. The grading decision was based on something other than course performance, unless the grade was a result of penalty for academic dishonesty.
2. The grading decision was based on standards that were unreasonably different from those applied to other students in the same section of that course.
3. The grading decision was based on standards that differed substantially and unreasonably from those previously articulated by the instructor.

To appeal a grade, the student should proceed as follows:

1. The student should prepare an appeal of the grade received in the course. This appeal must define the basis for the appeal and must present all relevant evidence supporting the student's case.
2. After preparing the appeal, the student should deliver this appeal to the course instructor and attempt to resolve the issue directly with the instructor. Written grade appeals must be delivered to the instructor no later than 10 business days after the start of the regular (fall or spring) semester immediately following the semester in which the contested grade was received. In the event that the course instructor is unavailable because of leave, illness, sabbatical, retirement, or resignation from the university, the course coordinator (first) or the department head (second) shall represent the instructor.
3. If after discussion with the instructor, the student is still dissatisfied, he or she can proceed with the appeal by emailing a copy of the appeal and a copy of a summary of the instructor/student meetings held in connection with the previous step to the Academic Standards Committee. All information must be submitted to the committee no later than 25 business days after the start of the semester immediately following the semester in which the contested grade was received.
4. On the basis of all information deemed pertinent to the grade appeal, the Academic Standards Committee will determine whether the grade should be revised. The decision rendered will be either:
   a. the original grading decision is upheld, or
   b. sufficient evidence exists to indicate a grade has been assigned unfairly.

In the latter case, the Academic Standards Committee will assign the student a new grade for the course. The committee's decision is final. The decision and supporting documentation will be delivered to the Faculty Senate, the office of the Executive Vice President for Academic Affairs, the student, the instructor, and the instructor's department head no later than 25 business days following the Faculty Senate's receipt of the grade appeal.

The schedule, but not the process, outlined above may be modified upon mutual agreement of the student, the course instructor, and the Academic Standards Committee.

Class Rank

Colorado School of Mines does not calculate class rank. The Registrar's Office will provide a letter stating this fact upon request if necessary for the submission of scholarship applications.

Minor Programs/Areas of Special Interest (ASI)

Established Minor Programs/Areas of Special Interest (ASI) are offered by undergraduate degree-granting departments and the Military Science Department. Additionally, Mines offers interdisciplinary minors and ASIs.

A Minor Program/Area of Special Interest declaration (which can be found in the Registrar's Office) should be submitted for approval at the time of application for graduation. If the minor or ASI is added after the application to graduate, it must be submitted to the Registrar's Office by the first day of the term in which the student is graduating.

Once the declaration form is submitted to the Registrar's Office, the student deciding not to complete the minor/ASI must officially drop the minor/ASI by notifying the Registrar's Office in writing. Should minor/ASI requirements not be complete at the time of graduation, the minor/ASI program will not be awarded. Minors/ASIs are not added after the BS degree is posted. Completion of the minor/ASI will be recorded on the student's official transcript. Students who return after completing a degree may not take courses solely to complete a minor with the expectation of having the minor added to the transcript. Minors/ASIs are not added after the BS degree is posted.

Please see the department for specific course requirements. For questions concerning changes in the sequence of minor/ASI courses after the declaration form is submitted, contact the Registrar's Office for assistance.

No more than half of the hours used for the minor or ASI may be transferred from other colleges or universities including AP, IB, or other high school or non-Mines credit. Some minor/ASI programs, however, have been established in collaboration with other institutions through formal articulation agreements and these may allow transfer credit exceeding this limit. For additional information on program-specific transfer credit limits, refer to the programs section of this Catalog.

At a minimum, Mines requires that any course used to fulfill a minor/ASI requirement be completed with a passing grade. Some programs offering minors/ASIs may, however, impose higher minimum grades for inclusion of the course in the minor/ASI. In these cases, the program specified minimum course grades take precedence. For additional information on program-specific minimum course grade requirements, refer to the programs section of this Catalog. At a minimum, to be awarded a minor/ASI, Mines requires students obtain a cumulative GPA of 2.0 or higher in all minor/ASI courses completed at Mines. All attempts at required minor/ASI courses are used in computing this minor/ASI GPA. Some programs offering minors/ASIs may, however, require a higher minimum cumulative GPA. In these cases, the program-specified GPA takes precedence. For additional information on program specific GPA requirements, refer to the programs section of this Catalog.

Each department or minor-oversight authority (in the case of interdisciplinary minors) defines a list of requirements that constitute a minor. The lists of requirements clearly delineate any specific courses needed for the minor, may include a set of courses from which the rest of the credits must be completed, and will clearly outline any other specific restrictions and/or requirements for obtaining the minor. Once recommended by Undergraduate Council and approved by Faculty Senate, the minor requirements will appear in the appropriate department or interdisciplinary sections of this catalog so that courses may be planned in advance in order for a student to receive a given minor(s).

The objective of a minor is to provide a depth of understanding and expertise to an area outside of, or complementary to, a student's degree. A minor is a thematically related set of academic activities leading to a transcript designation in addition to but separate from that granted by the student's degree.

Minors

All minors are created and awarded based on the following minimum requirements and limitations:

Minimum Credit Hours – 18.0

Minimum Hours Outside of Degree Requirements – 9.0

At least 9 of the hours required for the minor must not be used for any part of the degree other than free electives.

Minimum GPA – 2.0

A 2.0 grade point average, including all Mines graded courses used for the minor, must be met in order to receive the minor designation on the transcript. Transfer credit hours do not factor into the minor grade point average.

Level – At least 9 credits must be at the 300-level or above.

Content

There must be sufficient distinction between a degree and a minor obtained by the same student. In general, students may earn minors offered by the same department as their degree program, but the minor may not have the same name as the degree. For example, an Electrical Engineering degree-seeking student may earn a minor in Computer Science. However, degree-granting programs, with recommendation by Undergraduate Council and approval by Faculty Senate, may 1) specify minors that are excluded for their students due to insufficient distinction, and/or 2) add restrictions or additional requirements to the minimal requirements for their students to obtain a specific minor.

Areas of Special Interest (ASIs)

All ASIs are created and awarded based on the following minimum requirements and limitations:

Minimum Credit Hours – 12.0

Minimum Hours Outside of Degree Requirements – 9.0

At least 9 of the hours required for the ASI must not be used for any part of the degree other than free electives.

Minimum GPA – 2.0

A 2.0 grade point average, including all Mines graded courses used for the ASI, must be met in order to receive the ASI designation on the transcript. Transfer credit hours do not factor into the ASI grade point average.

Level - At least 9 credits must be at the 300-level or above.

Undergraduate Degree Requirements

Bachelor of Science Degree

Upon completion of the requirements and upon being recommended for graduation by the faculty, and approved by the Board of Trustees, the undergraduate receives one of the following degrees:

- Bachelor of Science (Applied Mathematics and Statistics)
- Bachelor of Science (Biochemistry)
- Bachelor of Science (Business Engineering and Management Science)
- Bachelor of Science (Ceramic Engineering)
- Bachelor of Science (Chemical Engineering)
- Bachelor of Science (Chemistry)
- Bachelor of Science (Civil Engineering)
- Bachelor of Science (Computer Science)
- Bachelor of Science (Construction Engineering)
- Bachelor of Science (Design Engineering)
- Bachelor of Science (Electrical Engineering)
- Bachelor of Science (Engineering Physics)
- Bachelor of Science (Environmental Engineering)
- Bachelor of Science (Geological Engineering)
- Bachelor of Science (Geophysical Engineering)
- Bachelor of Science (Mechanical Engineering)
- Bachelor of Science (Metallurgical and Materials Engineering)
- Bachelor of Science (Mining Engineering)
- Bachelor of Science (Petroleum Engineering)
- Bachelor of Science (Quantitative Biosciences and Engineering)

Graduation Requirements

To qualify for a Bachelor of Science degree from Colorado School of Mines, all candidates must satisfy the following requirements:

1. A minimum cumulative grade-point average of 2.000 for all academic work completed in residence.

2. A minimum cumulative grade-point average of 2.000 for courses in the candidate’s major.
3. A minimum of 30 hours credit in 300 and 400 series technical courses in residence, at least 15 of which are to be taken in the senior year.
4. A minimum of 19 hours in Culture and Society (CAS) courses.
5. The recommendation of their degree-granting department to the faculty.
6. The certification by the registrar that all required academic work is satisfactorily completed.
7. The recommendation of the faculty and approval of the Board of Trustees.

Seniors must submit an Application to Graduate upon completion of 90 hours (upon obtaining senior class standing). Applications are completed online through the student's Trailhead account.

Completed Minor and ASI forms are normally due to the Registrar's Office at the same as the application to graduate. If the minor or ASI is added later, it is due no later than the first day of the term in which the student is graduating.

It is the responsibility of students to monitor the progress of their degrees. It is also the student’s responsibility to contact the Registrar’s Office when there appears to be a discrepancy between the degree audit and the student’s records.

No students, graduate or undergraduate, will receive diplomas until they have complied with all the rules and regulations of Colorado School of Mines and settled all accounts with the school. Transcript of grades and other records will not be provided for any student or graduate who has an unsettled obligation of any kind to the school.

Multiple Degrees

A student wishing to complete two Bachelor of Science degrees must complete the first degree plus a minimum of thirty hours specific to the second degree program. The 30 (or more) hours required for the second degree may not include free electives and may not be double counted with any credit used to complete the first degree. The degree plan for the second degree must be approved by the advisor, the department head, and the Registrar’s Office representing Academic Affairs.

When two degrees are completed concurrently, the first degree is the one with fewer total hours required for graduation. In the case of a returning student, the first degree is the original completed degree. The two degrees may be in different colleges. The degree plan may include courses from multiple departments. Different catalogs may be used, one for each degree program. The student receives two separate diplomas. The transcript lists both degrees.

A student may not earn two degrees in the same content area because the course requirements, content, and titles do not significantly differ.

The following combinations are not allowable:

BS in Engineering, Mechanical Specialty & BS in Mechanical Engineering

BS in Engineering, Electrical Specialty & BS in Electrical Engineering

BS in Engineering, Environmental Specialty & BS in Environmental Engineering

BS in Engineering, Civil Specialty & BS in Civil Engineering

BS in Mathematics & Computer Science & BS in Applied Math and Statistics

BS in Mathematics & Computer Science & BS in Computer Science

BS in Chemical Engineering & BS in Chemical and Biochemical Engineering

Degree Posting and Grade Changes

Once the degree is posted, grade changes will be accepted for six weeks only. After six weeks has passed, no grade changes will be allowed for any courses on the official transcript.

Commencement Participation

To participate in May commencement, no more than 6 semester credit hours can remain outstanding after the spring term. The student must show proof of summer registration for these 6 or fewer credits in order to be placed on the list for August completion. To participate in December convocation, the undergraduate student must be registered for all courses that lead to completion of the degree at the end of the same fall term.

Courses Older Than 10 Years

For returning students who wish to use courses completed more than 10 years prior, contact the Registrar’s Office. These courses will not apply to current degrees without special approval from the degree-granting department, and the department in which the course is taught.

Programs and Departments

Applied Mathematics and Statistics

Program Description

The Applied Mathematics and Statistics Department (AMS) offers an undergraduate degree in which students are exposed to a breadth of coursework in computational mathematics, applied mathematics, and statistics. In the junior year, students may choose an area of emphasis in either Computational and Applied Mathematics (CAM), Statistics (STAT) or Data Science (DS). Each option emphasizes technical competence, problem solving, teamwork, projects, relation to other disciplines, verbal, written, and graphical skills.

In a broad sense, these programs stress the development of practical applications and techniques to enhance the overall attractiveness of applied mathematics and statistics majors to a wide range of employers in industry and government. More specifically, AMS utilizes a modeling "field session" to introduce concepts and techniques in mathematical modeling and the senior capstone experiences to engage high-level undergraduate students in problems of practical applicability for potential employers. These courses are designed to simulate an industrial job or research environment. The close collaboration with potential employers and professors improves communication between our students and the private sector, and sponsors from other disciplines on campus.

In addition to offering undergraduate and graduate degree programs, the department provides the teaching skills and technical expertise to develop capabilities in computational mathematics, applied mathematics, data science, and statistics for all Colorado School of Mines students.

Program Educational Objectives

Bachelor of Science in Applied Mathematics and Statistics

The Applied Mathematics and Statistics Program at Mines has established the following program educational objectives:

Students will demonstrate technical expertise within mathematics and statistics by:

- Designing and implementing solutions to practical problems in science and engineering.
- Using appropriate technology as a tool to solve problems in mathematics.

Students will demonstrate a breadth and depth of knowledge within mathematics by:

- Extending course material to solve original problems.
- Applying knowledge of mathematics to the solution of problems.
- Identifying, formulating and solving mathematics problems.
- Analyzing and interpreting statistical data.

Students will demonstrate an understanding and appreciation for the relationship of mathematics to other fields by:

- Applying mathematics and statistics to solve problems in other fields.
- Working in cooperative multidisciplinary teams.
- Choosing appropriate technology to solve problems in other disciplines.

Students will demonstrate an ability to communicate mathematics effectively by:

- Giving oral presentations.
- Completing written explanations.
- Interacting effectively in cooperative teams.
- Understanding and interpreting written material in mathematics.

Curriculum

The calculus sequence emphasizes mathematics applied to problems students are likely to see in other fields. This supports the curricula in other programs where mathematics is important and assists students who are under prepared in mathematics. Priorities in the mathematics curriculum include applied problems in the mathematics courses and ready utilization of mathematics in the science and engineering courses.

This emphasis on the utilization of mathematics continues through the upper-division courses. Another aspect of the curriculum is the use of a spiraling mode of learning in which concepts are revisited to deepen the students' understanding.

The applications, teamwork, assessment, and communications emphasis directly address ABET criteria and the Mines graduate profile. The curriculum offers the following two areas of emphasis:

Degree Requirements (Applied Mathematics and Statistics)

Computational and Applied Mathematics (CAM) EMPHASIS

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
PHGN100	PHYSICS I - MECHANICS			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				15.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS200	GLOBAL STUDIES			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS			3.0
MATH324	STATISTICAL MODELING			3.0
MATH332	LINEAR ALGEBRA or 342	3.0		3.0
FREE	FREE ELECTIVE			3.0
				15.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
MATH310	INTRODUCTION TO MATHEMATICAL MODELING			3.0

		lec	lab	sem.hrs
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
CSCIxxx	COMPUTING ELECTIVE[1]			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
MATH301	INTRODUCTION TO ANALYSIS	3.0		3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]			3.0
CAS Elective	Culture and Society mid-level			3.0
				15.0

Senior

Fall		**lec**	**lab**	**sem.hrs**
MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0		3.0
MATH431	MATHEMATICAL BIOLOGY			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
CAS ELECTIVE	Culture and Society mid-level			3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	4.0		4.0
MATH	MATHEMATICS-CAM ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-CAM ELECTIVE[2]	3.0		3.0
FREE	FREE ELECTIVE	3.0		3.0
CAS Elective	Culture and Society 400-level			3.0
				16.0

Total Semester Hrs: 121.0

[1] May be satisfied CSCI220, CSCI303, CSCI403, CSCI441, CSCI470, CSCI474, or CSCI478

Mathematics-CAM elective list. CAM students must choose at least 2 electives from this list. [2]

MATH440	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH457	INTEGRAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH459	ASYMPTOTICS	3.0
MATH472	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MATH500	LINEAR VECTOR SPACES	3.0
MATH501	APPLIED ANALYSIS	3.0
MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
MATH	Department approval required for courses not on this list.	

AMS Elective List. CAM students may choose up to 4 electives from this list to satisfy AMS Elective requirements. [2]

MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH432	SPATIAL STATISTICS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MATH437	MULTIVARIATE ANALYSIS	3.0
MATH438	STOCHASTIC MODELS	3.0
MATH439	SURVIVAL ANALYSIS	3.0
MATH482	STATISTICS PRACTICUM (CAPSTONE)	3.0
MATH531	THEORY OF LINEAR MODELS	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MATH535	MATHEMATICAL STATISTICS II	3.0
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
CSCI406	ALGORITHMS	3.0
MATH	Department approval required for courses not on this list.	

Statistics (STATS) EMPHASIS

Freshman

Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0
HASS100	NATURE AND HUMAN VALUES	3.0		3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
PHGN100	PHYSICS I - MECHANICS	3.0	3.0	4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				15.0

Sophomore

Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0

		lec	lab	sem.hrs
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS200	GLOBAL STUDIES			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS			3.0
MATH324	STATISTICAL MODELING			3.0
MATH332	LINEAR ALGEBRA or 342	3.0		3.0
FREE	FREE ELECTIVE			3.0
				15.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
MATH310	INTRODUCTION TO MATHEMATICAL MODELING			3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
CSCIxxx	COMPUTING ELECTIVE[1]			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH301	INTRODUCTION TO ANALYSIS			3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
CAS ELECTIVE	Culture and Society mid-level	3.0		3.0
				15.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
MATH436	ADVANCED STATISTICAL MODELING			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]			3.0
MATH	MATHEMATICS-STAT ELECTIVE[2]			3.0
CAS ELECTIVE	Culture and Society mid-level			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH437	MULTIVARIATE ANALYSIS			3.0
MATH482	STATISTICS PRACTICUM (CAPSTONE) (STAT Capstone)	4.0		4.0
MATH	MATHEMATICS-STAT ELECTIVE			3.0
CAS ELECTIVE	Culture and Society 400-level			3.0
FREE	FREE ELECTIVE	3.0		3.0
				16.0

Total Semester Hrs: 121.0

[1] May be satisfied CSCI220, CSCI303, CSCI403, CSCI441, CSCI470, CSCI474, or CSCI478

Mathematics-STAT Elective List. STAT students must choose at least 2 electives from this list. [2]

MATH432	SPATIAL STATISTICS	3.0
MATH438	STOCHASTIC MODELS	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
MATH531	THEORY OF LINEAR MODELS	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MATH535	MATHEMATICAL STATISTICS II	3.0
MATH	Department approval required for courses not on this list.	

Mathematics-CAM Elective List. STAT students may choose up to 4 electives from this list to satisfy AMS Elective requirements. [2]

MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH431	MATHEMATICAL BIOLOGY	3.0
MATH440	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH457	INTEGRAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH459	ASYMPTOTICS	3.0
MATH472	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0
MATH500	LINEAR VECTOR SPACES	3.0
MATH501	APPLIED ANALYSIS	3.0
MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CSCI406	ALGORITHMS	3.0
MATH	Department approval required for courses not on this list.	

Data Science (DS) Emphasis

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0
HASS100	NATURE AND HUMAN VALUES	3.0		3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
PHGN100	PHYSICS I - MECHANICS	3.0	3.0	4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				15.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS200	GLOBAL STUDIES			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS			3.0
MATH324	STATISTICAL MODELING			3.0
MATH332	LINEAR ALGEBRA or 342	3.0		3.0
FREE	FREE ELECTIVE			3.0
				15.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
MATH310	INTRODUCTION TO MATHEMATICAL MODELING			3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
CSCIxxx	COMPUTING ELECTIVE[1]			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH301	INTRODUCTION TO ANALYSIS			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
CSCI303	INTRODUCTION TO DATA SCIENCE			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
CAS ELECTIVE	Culture and Society mid-level	3.0		3.0
				15.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]			3.0
CAS ELECTIVE	Culture and Society mid-level			3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING			3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH482	STATISTICS PRACTICUM (CAPSTONE) (STAT Capstone)	4.0		4.0
MATH	MATHEMATICS-DS ELECTIVE[2]			3.0
MATH	MATHEMATICS-DS ELECTIVE[2]			3.0
CAS ELECTIVE	Culture and Society 400-level			3.0
FREE	FREE ELECTIVE	3.0		3.0
				16.0

Total Semester Hrs: 121.0

1 May be satisfied by CSCI220, CSCI403, CSCI441, CSCI474, or CSCI478

Mathematics-DS elective list. DS students must choose at least 2 electives from ths list [2]

MATH432	SPATIAL STATISTICS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MATH437	MULTIVARIATE ANALYSIS	3.0
MATH438	STOCHASTIC MODELS	3.0
MATH440	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH560	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I	3.0
MATH561	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II	3.0
CSCI403	DATA BASE MANAGEMENT	3.0

CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI406	ALGORITHMS	3.0
CSCI423	COMPUTER SIMULATION	3.0
CSCI475	INFORMATION SECURITY AND PRIVACY	3.0
MATH	Department approval required for courses not on this list.	

AMS Elective List. DS students may choose up to 4 electives from this list to satisfy AMS elective requirements [3]

MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH431	MATHEMATICAL BIOLOGY	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH457	INTEGRAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH459	ASYMPTOTICS	3.0
MATH472	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0
MATH500	LINEAR VECTOR SPACES	3.0
MATH501	APPLIED ANALYSIS	3.0
MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
MATH	Department approval required for courses not on this list.	

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- CSCI100 through CSCI799 inclusive
- MACS100 through MACS799 inclusive (Previous subject code)
- MATH100 through MATH799 inclusive

Degree Requirements (Applied Mathematics and Statistics)

Computational and Applied Mathematics (CAM) EMPHASIS

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
PHGN100	PHYSICS I - MECHANICS			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				15.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS200	GLOBAL STUDIES			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS			3.0
MATH324	STATISTICAL MODELING			3.0
MATH332	LINEAR ALGEBRA or 342	3.0		3.0
FREE	FREE ELECTIVE			3.0
				15.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
MATH310	INTRODUCTION TO MATHEMATICAL MODELING			3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
CSCIxxx	COMPUTING ELECTIVE[1]			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH301	INTRODUCTION TO ANALYSIS	3.0		3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0

MATH	MATHEMATICS-AMS ELECTIVE[2]			3.0
CAS Elective	Culture and Society mid-level			3.0
				15.0

Senior

Fall		lec	lab	sem.hrs
MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0		3.0
MATH431	MATHEMATICAL BIOLOGY			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
CAS ELECTIVE	Culture and Society mid-level			3.0
				15.0

Spring		lec	lab	sem.hrs
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	4.0		4.0
MATH	MATHEMATICS-CAM ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-CAM ELECTIVE[2]	3.0		3.0
FREE	FREE ELECTIVE	3.0		3.0
CAS Elective	Culture and Society 400-level			3.0
				16.0

Total Semester Hrs: 121.0

1 May be satisfied CSCI220, CSCI303, CSCI403, CSCI441, CSCI470, CSCI474, or CSCI478

Mathematics-CAM elective list. CAM students must choose at least 2 electives from this list. [2]

MATH440	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH457	INTEGRAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH459	ASYMPTOTICS	3.0
MATH472	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MATH500	LINEAR VECTOR SPACES	3.0
MATH501	APPLIED ANALYSIS	3.0
MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
MATH	Department approval required for courses not on this list.	

AMS Elective List. CAM students may choose up to 4 electives from this list to satisfy AMS Elective requirements. [2]

MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH432	SPATIAL STATISTICS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MATH437	MULTIVARIATE ANALYSIS	3.0
MATH438	STOCHASTIC MODELS	3.0
MATH439	SURVIVAL ANALYSIS	3.0
MATH482	STATISTICS PRACTICUM (CAPSTONE)	3.0
MATH531	THEORY OF LINEAR MODELS	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MATH535	MATHEMATICAL STATISTICS II	3.0
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
CSCI406	ALGORITHMS	3.0
MATH	Department approval required for courses not on this list.	

Statistics (STATS) EMPHASIS

Freshman

Fall		lec	lab	sem.hrs
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0
HASS100	NATURE AND HUMAN VALUES	3.0		3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				15.0

Spring		lec	lab	sem.hrs
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
PHGN100	PHYSICS I - MECHANICS	3.0	3.0	4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				15.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS200	GLOBAL STUDIES			3.0
				15.0

Spring		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS			3.0
MATH324	STATISTICAL MODELING			3.0
MATH332	LINEAR ALGEBRA or 342	3.0		3.0
FREE	FREE ELECTIVE			3.0
				15.0

Junior

Fall		lec	lab	sem.hrs
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
MATH310	INTRODUCTION TO MATHEMATICAL MODELING			3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
CSCIxxx	COMPUTING ELECTIVE[1]			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
				15.0

Spring		lec	lab	sem.hrs
MATH301	INTRODUCTION TO ANALYSIS			3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
CAS ELECTIVE	Culture and Society mid-level	3.0		3.0
				15.0

Senior

Fall		lec	lab	sem.hrs
MATH436	ADVANCED STATISTICAL MODELING			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]			3.0
MATH	MATHEMATICS-STAT ELECTIVE[2]			3.0
CAS ELECTIVE	Culture and Society mid-level			3.0
				15.0

Spring		lec	lab	sem.hrs
MATH437	MULTIVARIATE ANALYSIS			3.0
MATH482	STATISTICS PRACTICUM (CAPSTONE) (STAT Capstone)	4.0		4.0
MATH	MATHEMATICS-STAT ELECTIVE			3.0
CAS ELECTIVE	Culture and Society 400-level			3.0
FREE	FREE ELECTIVE	3.0		3.0
				16.0

Total Semester Hrs: 121.0

[1] May be satisfied CSCI220, CSCI303, CSCI403, CSCI441, CSCI470, CSCI474, or CSCI478

Mathematics-STAT Elective List. STAT students must choose at least 2 electives from this list. [2]

MATH432	SPATIAL STATISTICS	3.0
MATH438	STOCHASTIC MODELS	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
MATH531	THEORY OF LINEAR MODELS	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MATH535	MATHEMATICAL STATISTICS II	3.0
MATH	Department approval required for courses not on this list.	

Mathematics-CAM Elective List. STAT students may choose up to 4 electives from this list to satisfy AMS Elective requirements. [2]

MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH431	MATHEMATICAL BIOLOGY	3.0
MATH440	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH457	INTEGRAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH459	ASYMPTOTICS	3.0
MATH472	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0
MATH500	LINEAR VECTOR SPACES	3.0
MATH501	APPLIED ANALYSIS	3.0
MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CSCI406	ALGORITHMS	3.0
MATH	Department approval required for courses not on this list.	

Data Science (DS) Emphasis

Freshman

Fall		lec	lab	sem.hrs
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0

		lec	lab	sem.hrs
HASS100	NATURE AND HUMAN VALUES	3.0		3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				15.0

Spring		lec	lab	sem.hrs
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
PHGN100	PHYSICS I - MECHANICS	3.0	3.0	4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				15.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS200	GLOBAL STUDIES			3.0
				15.0

Spring		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS			3.0
MATH324	STATISTICAL MODELING			3.0
MATH332	LINEAR ALGEBRA or 342	3.0		3.0
FREE	FREE ELECTIVE			3.0
				15.0

Junior

Fall		lec	lab	sem.hrs
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
MATH310	INTRODUCTION TO MATHEMATICAL MODELING			3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
CSCIxxx	COMPUTING ELECTIVE[1]			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
				15.0

Spring		lec	lab	sem.hrs
MATH301	INTRODUCTION TO ANALYSIS			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
CSCI303	INTRODUCTION TO DATA SCIENCE			3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
CAS ELECTIVE	Culture and Society mid-level	3.0		3.0
				15.0

Senior

Fall		lec	lab	sem.hrs
MATH	MATHEMATICS-AMS ELECTIVE[2]	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE[2]			3.0
CAS ELECTIVE	Culture and Society mid-level			3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING			3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS			3.0
				15.0

Spring		lec	lab	sem.hrs
MATH482	STATISTICS PRACTICUM (CAPSTONE) (STAT Capstone)	4.0		4.0
MATH	MATHEMATICS-DS ELECTIVE[2]			3.0
MATH	MATHEMATICS-DS ELECTIVE[2]			3.0
CAS ELECTIVE	Culture and Society 400-level			3.0
FREE	FREE ELECTIVE	3.0		3.0
				16.0

Total Semester Hrs: 121.0

[1] May be satisfied by CSCI220, CSCI403, CSCI441, CSCI474, or CSCI478

Mathematics-DS elective list. DS students must choose at least 2 electives from ths list [2]

MATH432	SPATIAL STATISTICS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MATH437	MULTIVARIATE ANALYSIS	3.0
MATH438	STOCHASTIC MODELS	3.0
MATH440	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH560	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I	3.0
MATH561	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI406	ALGORITHMS	3.0
CSCI423	COMPUTER SIMULATION	3.0
CSCI475	INFORMATION SECURITY AND PRIVACY	3.0
MATH	Department approval required for courses not on this list.	

AMS Elective List. DS students may choose up to 4 electives from this list to satisfy AMS elective requirements [3]

MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH431	MATHEMATICAL BIOLOGY	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH457	INTEGRAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH459	ASYMPTOTICS	3.0
MATH472	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0
MATH500	LINEAR VECTOR SPACES	3.0
MATH501	APPLIED ANALYSIS	3.0
MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
MATH	Department approval required for courses not on this list.	

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- CSCI100 through CSCI799 inclusive
- MACS100 through MACS799 inclusive (Previous subject code)
- MATH100 through MATH799 inclusive

Overview

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14) section of the Mines Catalog (p. 2). The Department of Applied Mathematics and Statistics offers the following:

Minors are available in:

Applied Mathematics and Statistics (AMS)

Required Courses		
MATH201	INTRODUCTION TO STATISTICS	3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0
or MATH235	DIFFERENTIAL EQUATIONS HONORS	
MATH332	LINEAR ALGEBRA	3.0
or MATH342	HONORS LINEAR ALGEBRA	
Plus 9 credits from any MATHxxx courses, at least one of which at the 400-level or above. Recall that at most 9 credits can simultaneously satisfy both a minor requirement and another program (major or minor) requirement.		

To complete an AMS Minor, students must choose 9 credits from MATHxxx courses. The following courses from other departments will also be accepted:

CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CSCI406	ALGORITHMS	3.0
CSCI441	COMPUTER GRAPHICS	3.0
CSCI444	ADVANCED COMPUTER GRAPHICS	3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING	3.0
CSCI474	INTRODUCTION TO CRYPTOGRAPHY	3.0

Courses

MATH100. INTRODUCTORY TOPICS FOR CALCULUS. 3.0 Semester Hrs.

(S) An introduction and/or review of topics which are essential to the background of an undergraduate student at CSM. This course serves as a preparatory course for the Calculus curriculum and includes material from Algebra, Trigonometry, Mathematical Analysis, and Calculus. Topics include basic algebra and equation solving, solutions of inequalities, trigonometric functions and identities, functions of a single variable, continuity, and limits of functions. Does not apply toward undergraduate degree or GPA. 3 hours lecture; 3 semester hours.

MATH111. CALCULUS FOR SCIENTISTS AND ENGINEERS I. 4.0 Semester Hrs.

(I, II, S) First course in the calculus sequence, including elements of plane geometry. Functions, limits, continuity, derivatives and their application. Definite and indefinite integrals; Prerequisite: precalculus. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MATH112. CALCULUS FOR SCIENTISTS AND ENGINEERS II. 4.0 Semester Hrs.

Equivalent with MATH122,

Vectors, applications and techniques of integration, infinite series, and an introduction to multivariate functions and surfaces. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1. Prerequisite: Grade of C- or better in MATH111.

MATH122. CALCULUS FOR SCIENTISTS AND ENGINEERS II HONORS. 4.0 Semester Hrs.

Equivalent with MATH112,

Same topics as those covered in MATH112 but with additional material and problems. Prerequisite: Grade of C- or better in MATH111.

MATH198. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH201. INTRODUCTION TO STATISTICS. 3.0 Semester Hrs.
Equivalent with MATH323,
This course is an introduction to Statistics, including fundamentals of experimental design and data collection, the summary and display of data, propagation of error, interval estimation, hypothesis testing, and linear regression with emphasis on applications to science and engineering. Prerequisite: MATH111.
Course Learning Outcomes

- Choose appropriate descriptive statistics and graphical displays to summarize a data set.
- Distinguish between commonly used random variables and sampling distributions in order to identify the appropriate statistical tools based on the context of a given problem.
- Identify, formulate, and evaluate appropriate tools for statistical inference based on the context of a given problem.
- Disseminate/Communicate statistical analysis.

MATH213. CALCULUS FOR SCIENTISTS AND ENGINEERS III. 4.0 Semester Hrs.
Multivariable calculus, including partial derivatives, multiple integrals, and vector calculus. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1. Prerequisites: Grade of C- or better in MATH112 or MATH122. Corequisites: CSCI128 or CSCI102.

MATH223. CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS. 4.0 Semester Hrs.
Same topics as those covered in MATH213 but with additional material and problems. Prerequisite: MATH112 with a grade of B- or higher, MATH112 with a grade of B- or higher.

MATH225. DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
Classical techniques for first and higher order equations and systems of equations. Laplace transforms. Phase-plane and stability analysis of non-linear equations and systems. Applications from physics, mechanics, electrical engineering, and environmental sciences. Prerequisites: Grade of C- or better in MATH112 or MATH122. Corequisites: CSCI128 or CSCI102. 3 hours lecture; 3 semester hours.

MATH235. DIFFERENTIAL EQUATIONS HONORS. 3.0 Semester Hrs.
Same topics as those covered in MATH225 but with additional material and problems. 3 hours lecture; 3 semester hours. Prerequisite: Grade of B- or better in MATH112 or MATH 113 or MATH122.

MATH298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH300. FOUNDATIONS OF ADVANCED MATHEMATICS. 3.0 Semester Hrs.
(WI) This course is an introduction to communication in mathematics. This writing intensive course provides a transition from the Calculus sequence to theoretical mathematics curriculum in CSM. Topics include logic and recursion, techniques of mathematical proofs, reading and writing proofs. 3 hours lecture; 3 semester hours. Prerequisite: MATH112 or MATH122.
Course Learning Outcomes

- Apply the rules of logic in order to construct proofs. In particular, students should be able to work symbolically with connectives and quantifiers to produce logically valid, correct and clear arguments.
- Apply abstract definitions and previous results (from areas such as set theory, discrete mathematics, introductory analysis, or introductory abstract algebra) as well as create intuition-forming examples or counterexamples in order to prove or disprove a conjecture.
- Construct direct and indirect proofs and proofs by induction and determine the appropriateness of each type in a particular setting (such as set theory, discrete mathematics, introductory analysis, or introductory abstract algebra).
- Write solutions to problems and proofs of theorems that meet rigorous standards based on content, organization and coherence, argument and support, and style and mechanics.
- Analyze and critique proofs with respect to logic and correctness.

MATH301. INTRODUCTION TO ANALYSIS. 3.0 Semester Hrs.
Equivalent with MATH401,
This course is a first course in real analysis that lays out the context and motivation of analysis in terms of the transition from power series to those less predictable series. The course is taught from a historical perspective. It covers an introduction to the real numbers, sequences and series and their convergence, real-valued functions and their continuity and differentiability, sequences of functions and their pointwise and uniform convergence, and Riemann-Stieltjes integration theory. 3 hours lecture; 3 semester hours. Prerequisite: MATH300.

MATH307. INTRODUCTION TO SCIENTIFIC COMPUTING. 3.0 Semester Hrs.
Equivalent with CSCI407,MATH407,
This course is designed to introduce scientific computing to scientists and engineers. Students in this course will be taught various numerical methods and programming techniques to solve basic scientific problems. Emphasis will be made on implementation of various numerical and approximation methods to efficiently simulate several applied mathematical models. 3 hours lecture; 3 semester hours. Prerequisite: MATH213 or MATH223; CSCI102 or CSCI128 or CSCI200. Co-requisite: MATH225 or MATH235.

MATH310. INTRODUCTION TO MATHEMATICAL MODELING. 3.0 Semester Hrs.
An introduction to modeling and communication in mathematics. A writing intensive course providing a transition from the core math sequence to the upper division AMS curriculum. Topics include a variety of mathematical and statistical modeling techniques. Students will formulate and solve applied problems and will present results orally and in writing. In addition, students will be introduced to the mathematics software that will be used in upper division courses. Prerequisite: MATH201, MATH213, MATH225; CSCI128.
Course Learning Outcomes

- Formulate and investigate mathematical and statistical models
- Identify mulitple types of models and techniques
- Communicate the results of a modeling study in writing and orally

MATH324. STATISTICAL MODELING. 3.0 Semester Hrs.
Linear regression, analysis of variance, and design of experiments, focusing on the construction of models and evaluation of their fit. Techniques covered will include stepwise and best subsets regression, variable transformations, and residual analysis. Emphasis will be placed on the analysis of data with statistical software. Prerequisite: MATH201.

MATH332. LINEAR ALGEBRA. 3.0 Semester Hrs.
Systems of linear equations, matrices, determinants and eigenvalues. Linear operators. Abstract vector spaces. Applications selected from linear programming, physics, graph theory, and other fields. Prerequisite: CSCI128; MATH112, MATH122, or PHGN100.

MATH334. INTRODUCTION TO PROBABILITY. 3.0 Semester Hrs.
An introduction to the theory of probability essential for problems in science and engineering. Topics include axioms of probability, combinatorics, conditional probability and independence, discrete and continuous probability density functions, expectation, jointly distributed random variables, Central Limit Theorem, laws of large numbers. 3 hours lecture, 3 semester hours. Prerequisite: CSCI128 or CSCI102; MATH213, MATH223.

MATH335. INTRODUCTION TO MATHEMATICAL STATISTICS. 3.0 Semester Hrs.
An introduction to the theory of statistics essential for problems in science and engineering. Topics include sampling distributions, methods of point estimation, methods of interval estimation, significance testing for population means and variances and goodness of fit, linear regression, analysis of variance. 3 hours lecture, 3 semester hours. Prerequisite: MATH334.

MATH342. HONORS LINEAR ALGEBRA. 3.0 Semester Hrs.
Same topics as those covered in MATH332 but with additional material and problems as well as a more rigorous presentation. 3 hours lecture; 3 semester hours. Prerequisite: MATH213, MATH223.

MATH398. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH399. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH408. COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
This course is designed to introduce computational methods to scientists and engineers for developing differential equations based computer models. Students in this course will be taught various numerical methods and programming techniques to simulate systems of nonlinear ordinary differential equations. Emphasis will be on implementation of various numerical and approximation methods to efficiently simulate several systems of nonlinear differential equations. Prerequisite: MATH307. 3 hours lecture, 3 semester hours.

MATH431. MATHEMATICAL BIOLOGY. 3.0 Semester Hrs.
This course will discuss methods for building and solving both continuous and discrete mathematical models. These methods will be applied to population dynamics, epidemic spread, pharmacokinetics and modeling of physiologic systems. Modern Control Theory will be introduced and used to model living systems. Some concepts related to self-organizing systems will be introduced. Prerequisite: MATH307, MATH310 or BIOL300, and MATH332 or MATH342.
Course Learning Outcomes

- Describe the assumptions and implementations of some of the classical models of mathematical biology in your own words.
- Derive models for biological phenomena including both discrete and continuous classes of models.
- Solve models using both analytical and numerical techniques.
- Apply techniques for model analysis and interpret results.
- Generate and professionally communicate novel results in mathematical biology.

MATH432. SPATIAL STATISTICS. 3.0 Semester Hrs.
Modeling and analysis of data observed in a 2- or 3-dimensional region. Random fields, variograms, covariances, stationarity, nonstationarity, kriging, simulation, Bayesian hierarchical models, spatial regression, SAR, CAR, QAR, and MA models, Geary/Moran indices, point processes, K-function, complete spatial randomness, homogeneous and inhomogeneous processes, marked point processes. Prerequisite: MATH324, MATH332, MATH335.

MATH433. TIME SERIES AND ITS APPLICATIONS. 3.0 Semester Hrs.
Equivalent with BELS331,BELS433,MACS433,MATH331,
Exploratory Analysis of Time Series, Stationary Time Series, Autocorrelation and Partial Autocorrelation, Autoregressive Moving Average (ARMA) Models, Forecasting, Estimation, ARIMA Models for Nonstationary Data, Multiplicative Seasonal ARIMA Models, The Spectral Density, Periodogram and Discrete Fourier Transform, Spectral Estimation, Multiple Series and Cross-Spectra, Linear Filters, Long Memory ARMA and Fractional Differencing, GARCH Models, Threshold Models, Regression with Autocorrelated Errors, Lagged Regression, Multivariate ARMAX Models. Prerequisite: MATH324, MATH335.
Course Learning Outcomes

- This course is designed to be useful for students facing the analysis of time-correlated data in the physical, biological, and social sciences.

MATH436. ADVANCED STATISTICAL MODELING. 3.0 Semester Hrs.
Modern methods for constructing and evaluating statistical models. Topics include generalized linear models, generalized additive models, hierarchical Bayes methods, and resampling methods. Time series models, including moving average, autoregressive, and ARIMA models, estimation and forecasting, confidence intervals. 3 hours lecture; 3 semester hours. Prerequisite: MATH332, MATH324.
Course Learning Outcomes

- Fit and interpret standard and weighted linear models
- Fit and interpret ANOVA models
- Fit and interpret generalized linear models
- Fit models to time series data
- Perform diagnostic tests on statistical models

MATH437. MULTIVARIATE ANALYSIS. 3.0 Semester Hrs.
Introduction to applied multivariate techniques for data analysis. Topics include principal components, cluster analysis, MANOVA and other methods based on the multivariate Gaussian distribution, discriminant analysis, classification with nearest neighbors. 3 hours lecture; 3 semester hours. Prerequisite: MATH335 or MATH201, MATH332 or MATH342, MATH324.

MATH438. STOCHASTIC MODELS. 3.0 Semester Hrs.
(II) An introduction to stochastic models applicable to problems in engineering, physical science, economics, and operations research. Markov chains in discrete and continuous time, Poisson processes, and topics in queuing, reliability, and renewal theory. Prerequisite: MATH332, MATH334.

MATH439. SURVIVAL ANALYSIS. 3.0 Semester Hrs.
Basic theory and practice of survival analysis. Topics include survival and hazard functions, censoring and truncation, parametric and non-parametric inference, hypothesis testing, the proportional hazards model, model diagnostics. 3 hours lecture; 3 semester hours. Prerequisite: MATH335.

MATH440. PARALLEL SCIENTIFIC COMPUTING. 3.0 Semester Hrs.
Equivalent with CSCI440,
This course is designed to facilitate students' learning of high-performance computing concepts and techniques to efficiently perform large-scale mathematical modelling and data analysis using modern high-performance architectures (e.g. multi-core processors, multiple processors, and/or accelerators). Emphasis will be placed on analysis and implementation of various scientific computing algorithms in high-level languages using their interfaces for parallel or accelerated computing. Use of scripting to manage HPC workflows is included. Prerequisite: MATH307, CSCI200.

MATH454. COMPLEX ANALYSIS. 3.0 Semester Hrs.
The complex plane. Analytic functions, harmonic functions. Mapping by elementary functions. Complex integration, power series, calculus of residues. Conformal mapping. Prerequisite: MATH225 or MATH235 and MATH213 or MATH223. 3 hours lecture, 3 semester hours.

MATH455. PARTIAL DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
Linear partial differential equations, with emphasis on the classical second-order equations: wave equation, heat equation, Laplace's equation. Separation of variables, Fourier methods, Sturm-Liouville problems. Prerequisites: MATH225 or MATH235 and MATH213 or MATH223. 3 hours lecture; 3 semester hours.

MATH457. INTEGRAL EQUATIONS. 3.0 Semester Hrs.
This is an introductory course on the theory and applications of integral equations. Abel, Fredholm and Volterra equations. Fredholm theory: small kernels, separable kernels, iteration, connections with linear algebra and Sturm-Liouville problems. Applications to boundary-value problems for Laplace's equation and other partial differential equations. Prerequisites: MATH332 or MATH342, and MATH455. 3 hours lecture; 3 semester hours.

MATH458. ABSTRACT ALGEBRA. 3.0 Semester Hrs.
This course is an introduction to the concepts of contemporary abstract algebra and applications of those concepts in areas such as physics and chemistry. Topics include groups, subgroups, isomorphisms and homomorphisms, rings, integral domains and fields. Prerequisites: MATH300. 3 hours lecture; 3 semester hours.

MATH459. ASYMPTOTICS. 3.0 Semester Hrs.
Equivalent with MATH559,
Asymptotic methods are used to find approximate solutions to problems when exact solutions are unavailable or too complicated to be useful. A broad range of asymptotic methods is developed, covering algebraic problems, integrals and differential equations. Prerequisites: MATH213 and MATH225. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Use asymptotic methods to solve algebraic problems.
- Use asymptotic methods to estimate integrals
- Use asymptotic methods to solve differential equations.

MATH470. MATHEMATICAL MODELING OF SPATIAL PROCESSES IN BIOLOGY. 3.0 Semester Hrs.
(II) This course is an introduction to mathematical modeling of spatial processes in biology. The emphasis is on partial differential equation models from a diverse set of biological topics such as cellular homeostasis, muscle dynamics, neural dynamics, calcium handling, epidemiology, and chemotaxis. We will survey a variety of models and analyze their results in the context of the biology. Mathematically, we will examine the diffusion equation, advection equation, and combinations of the two that include reactions. There will be a significant computational component to the course including bi-weekly computational labs; students will solve the model equations and perform computations using MATLAB. Prerequisite: MATH431, MATH455 or equivalent courses and familiarity with MATLAB.
Course Learning Outcomes

- Describe classical spatial-temporal models in mathematical biology including diffusion-reaction, advection-reaction, and advection-diffusion-reaction
- Derive partial differential equations models for spatial-temporal phenomena
- Implement analytical and numerical techniques to solve and analyze spatial-temporal models
- Assimilate current literature, extend it in a final project that advances the field, and communicate results professionally and effectively

MATH472. MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE. 3.0 Semester Hrs.
This course will focus on mathematical and computational techniques applied to neuroscience. Topics will include nonlinear dynamics, hysteresis, the cable equation, and representative models such as Wilson-Cowan, Hodgkin-Huxley, and FitzHugh-Nagumo. Applications will be motivated by student interests. In addition to building basic skills in applied math, students will gain insight into how mathematical sciences can be used to model and solve problems in neuroscience; develop a variety of strategies (computational, theoretical, etc.) with which to approach novel mathematical situations; and hone skills for communicating mathematical ideas precisely and concisely in an interdisciplinary context. In addition, the strong computational component of this course will help students to develop computer programming skills and apply appropriate technological tools to solve mathematical problems. 3 hours lecture; 3 semester hours. Prerequisite: MATH431.
Course Learning Outcomes

- Describe the classical models of mathematical neuroscience including Hodgkin-Huxley, Wilson-Cowan, and FitzHugh-Nagumo
- Implement analytical and numerical techniques to analyze models at different spatial and temporal scales;
- Apply concepts from nonlinear dynamics including phase plane analysis, bifurcation theory, and model reduction techniques to analyze models in neuroscience.
- Assimilate current literature, extend it in a final project that advances the field, and communicate results professionally and effectively.

MATH482. STATISTICS PRACTICUM (CAPSTONE). 3.0 Semester Hrs.
This is the capstone course in the Statistics option. Students will apply statistical principles to data analysis through advanced work, leading to a written report and an oral presentation. Choice of project is arranged between the student and the individual faculty member who will serve as advisor. Prerequisite: MATH335, MATH324, MATH436.
Course Learning Outcomes

- Gain hands-on data analysis experience on a substantial problem seeing it all the way through.
- Communicate effectively with clients, who might have limited statistical background.
- Develop well-documented and reproducible code.
- Document results in a technical report and potentially co-author a scientific publication.

MATH484. MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE). 3.0 Semester Hrs.
This is the capstone course in the Computational and Applied Mathematics option. Students will apply computational and applied mathematics modeling techniques to solve complex problems in biological, engineering and physical systems. Mathematical methods and algorithms will be studied within both theoretical and computational contexts. The emphasis is on how to formulate, analyze and use nonlinear modeling to solve typical modern problems. Prerequisite: MATH431, MATH307, MATH455.
Course Learning Outcomes

- Construct, interpret, and critique fundamental models of physical, chemical, and biological systems throughout the fundamental and applied sciences.
- Utilize computational tools, such as MATLAB, to simulate behavior arising from mathematical models
- Describe and interpret, via oral and written means, pertinent information obtained from mathematical analysis and simulation in order to draw scientific conclusions concerning applied model

MATH491. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
(I) (WI) Individual investigation under the direction of a department faculty member. Written report required for credit. Variable - 1 to 3 semester hours. Repeatable for credit to a maximum of 12 hours.

MATH498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH499. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Department Head

G. Gustave Greivel, Teaching Professor

Professors

Greg Fasshauer

Mahadevan Ganesh

Paul A. Martin

Doug Nychka

Stephen Pankavich

Associate Professors

Soutir Bandyopadhyay

Cecilia Diniz Behn

Dorit Hammerling

Luis Tenorio

Assistant professors

Eileen Martin

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Samy Wu Fung

Teaching Professors

Terry Bridgman

Debra Carney

Holly Eklund

Mike Mikucki

Mike Nicholas

Scott Strong

Jennifer Strong

Rebecca Swanson

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John Griesmer

Nathan Lenssen

Daisy Philtron

Emeriti Professors

Bernard Bialecki

William C. Navidi

William R. Astle

Norman Bleistein

Ardel J. Boes

Austin R. Brown

John A. DeSanto

Graeme Fairweather

Raymond R. Gutzman

Frank G. Hagin

Donald C.B. Marsh

Willy Hereman

Steven Pruess

Emeriti Associate Professors

Barbara B. Bath

Ruth Maurer

Chemical and Biological Engineering

Program Description

The Chemical and Biological Engineering Department offers a Bachelor of Science in Chemical Engineering, with optional Biological Engineering, Process Engineering, or Honors Research tracks.

Generally, the fields of chemical and biological engineering are extremely broad and encompass all technologies and industries where chemical processing is utilized in any form. Students with baccalaureate (BS) Chemical Engineering degrees from Mines can find employment in many diverse fields, including advanced materials synthesis and processing, product and process research and development, food and pharmaceutical processing and synthesis, biochemical and biomedical materials and products, microelectronics manufacturing, petroleum and petrochemical processing, and process and product design. Students in the Biological Engineering, Process Engineering, or Honors Research track take 12 credits of technical and chemical engineering electives designed to provide additional focus in these areas. The Biological and Process Engineering tracks are open to all students. The Honors Research track requires students to apply and be accepted. Alternatively, students can earn their degree without being in a track, customizing their electives without any restrictions.

The practice of chemical engineering draws from the fundamentals of biology, chemistry, mathematics, and physics. Accordingly, undergraduate students must initially complete a program of study that stresses these basic fields of science. Chemical engineering coursework blends these four disciplines into a series of engineering fundamentals relating to how materials are produced and processed both in the laboratory and in large industrial-scale facilities. Courses such as fluid mechanics, heat and mass transfer, thermodynamics, reaction kinetics, and chemical process control are at the heart of the chemical engineering curriculum at Mines. In addition, it is becoming increasingly important for engineers to understand how biological and microscopic, molecular-level properties can influence the macroscopic behavior of materials, biological, and chemical systems. This somewhat unique focus is first introduced at Mines through the physical and organic chemistry sequences, and the theme is continued and developed within the chemical engineering curriculum via material and projects introduced in advanced courses. Our undergraduate program at Mines is exemplified by intensive integration of computer-aided simulation and computer-aided process modeling in the curriculum and by our unique approach to teaching of the unit operations laboratory sequence. The unit operations lab course is offered only in the summer as a six-week intensive session. Here, the fundamentals of heat, mass, and momentum transfer and applied thermodynamics are reviewed in a practical, applications-oriented setting. The important skills of teamwork, critical thinking, time management, and oral and written technical communications skills are also stressed in this course.

Facilities for the study of chemical and biological engineering at the Colorado School of Mines are among the best in the nation. Specialized undergraduate laboratory facilities exist for studying polymer properties, measuring reaction kinetics, characterizing transport phenomena, and for studying several typical chemical unit operations. Our undergraduate research program is open to highly qualified students and provides our undergraduates with the opportunity to carry out independent research or to join a graduate research team. This program has been highly successful and our undergraduate chemical engineering students have won several national competitions and awards based on research conducted while pursuing their baccalaureate degrees. We also have a cooperative (co-op) education program in which students can earn course credit while gaining work experience in industry.

The Bachelor of Science in Chemical Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission's General Criteria and Program Criteria for Chemical, Biochemical, Biomolecular, and Similarly named Engineering Programs.

Please visit our webpage for contact points and more information on the degree program, including details on how to apply for the Honors Research track at https://chemeng.mines.edu/.

PRIMARY CONTACT

Professor Rachel Morrish, Associate Department Head

rmorrish@mines.edu

Program Educational Objectives (Bachelor of Science in Chemical Engineering)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET accreditation criteria, the Chemical and Biological Engineering Department at CSM has established three program educational objectives for all of its graduates. Our graduates within three to five years of completing their degree will:

- Be in graduate school or in the workforce utilizing their education in chemical engineering fundamentals
- Be applying their knowledge of and skills in engineering fundamentals in conventional areas of chemical engineering and in contemporary and growing fields
- Have demonstrated both their commitment to continuing to develop personally and professionally and an appreciation for the ethical and social responsibilities associated with being an engineer and a world citizen

Student Learning Outcomes

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Combined Baccalaureate/Masters Degree Program

The Chemical and Biological Engineering Department offers the opportunity to begin work on a Master of Science (with or without thesis) degree while completing the requirements of the BS degree. These combined BS/MS degrees are designed to allow undergraduates engaged in research, or simply interested in furthering their studies beyond a BS degree, to apply their experience and interest to an advanced degree.

Students enrolled in Mines' combined undergraduate/graduate program may double count up to six credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with "B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

The requirements for the (non-thesis) MS degree consist of the four core graduate courses:

CBEN507	APPLIED MATHEMATICS IN CHEMICAL ENGINEERING	3.0
or CBEN420/505	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	
CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	ADVANCED TRANSPORT PHENOMENA	3.0
or CBEN430/530	TRANSPORT PHENOMENA	
CBEN518	REACTION KINETICS AND CATALYSIS	3.0
or CBEN519	ADVANCED TOPICS IN HETEROGENEOUS CATALYSIS	
ELECT	Approved Electives	18.0
Total Semester Hrs		**30.0**

It is expected that a student would be able to complete both degrees in four and a half to five years. To take advantage of the combined program, students are encouraged to engage in research and take some graduate coursework during their senior year. The application process and requirements are identical to our normal MS degree programs. Applications may be completed online and require three letters of recommendation and a statement of purpose. For students who intend to begin the BS/MS program in fall, applications are due by July 1. The deadline is November 1 for students intending to enroll in the spring semester. Students must have a GPA greater than 3.0 to be considered for the program. Interested students are encouraged to get more information from their advisor and/or the current faculty member in charge of Graduate Affairs.

Curriculum

The Chemical Engineering curriculum is structured according to the goals outlined above. Accordingly, the programs of study are organized to include three semesters of science and general engineering fundamentals followed by five semesters of chemical engineering fundamentals and applications.

A. Chemical Engineering Fundamentals

The following courses represent the basic knowledge component of the Chemical Engineering curriculum at Mines.

CBEN201	MATERIAL AND ENERGY BALANCES	3.0
CBEN307	FLUID MECHANICS	3.0
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER	4.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS	3.0

B. Chemical Engineering Applications

The following courses are applications-oriented courses that build on the student's basic knowledge of science and engineering fundamentals:

CBEN312	UNIT OPERATIONS LABORATORY	3.0
CBEN313	UNIT OPERATIONS LABORATORY	3.0
CBEN402	CHEMICAL ENGINEERING DESIGN	3.0
CBEN403	PROCESS DYNAMICS AND CONTROL	3.0
CBEN414	CHEMICAL PROCESS SAFETY	1.0
CBEN418	KINETICS AND REACTION ENGINEERING	3.0
Technical Electives for Chemical Engineering		

C. Electives for Chemical Engineering

Chemical Engineering majors have elective credit requirements that may be fulfilled with several different courses. Technical Electives I and II are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement. CBEN electives are courses offered by the CBE department with engineering content, one of the two required classes must be at the 400-level. Lastly, one CBEN/CHGN elective is required at the 300-level or higher. Some or all of these electives may be grouped together to earn a specialty track in chemical engineering as described below.

D. Specialty Tracks in Chemical Engineering

NOTE: Below is a suggested curriculum path. Electives may be taken any time they fit into your schedule, but note that not all courses are offered all semesters. Please refer to https://chemeng.mines.edu/undergraduate-program/ for the most updated flowsheet.

Degree Requirements (Chemical Engineering)

Freshman

Fall		lec	lab	sem.hrs
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
				16.0

Spring		lec	lab	sem.hrs
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
S&W ELECT	SUCCESS & WELLNESS COURSE			1.0
				16.0

Sophomore

Fall		lec	lab	sem.hrs
CBEN210	INTRO TO THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0

Spring		lec	lab	sem.hrs
CBEN200	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING			3.0
CBEN201	MATERIAL AND ENERGY BALANCES			3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
				15.0

Junior

Fall		lec	lab	sem.hrs
CBEN307	FLUID MECHANICS			3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS			3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY			1.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0	4.0
EBGN321	ENGINEERING ECONOMICS			3.0
HASS200	GLOBAL STUDIES			3.0
				17.0

Spring		lec	lab	sem.hrs
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER			4.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS			3.0
CBEN403	PROCESS DYNAMICS AND CONTROL			3.0
ELECTIVE	CULTURE AND SOCIETY (CAs) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
TECH	TECH ELECTIVE			3.0
				16.0

Summer		lec	lab	sem.hrs
CBEN312	UNIT OPERATIONS LABORATORY			3.0
CBEN313	UNIT OPERATIONS LABORATORY			3.0
				6.0

Senior

Fall		lec	lab	sem.hrs
CBEN402	CHEMICAL ENGINEERING DESIGN			3.0
CBEN414	CHEMICAL PROCESS SAFETY			1.0
CBEN418	KINETICS AND REACTION ENGINEERING			3.0
CBEN ELECT	CHEMICAL ENGINEERING ELECTIVE			3.0
TECH	TECH ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
				16.0

Spring		lec	lab	sem.hrs
CBEN ELECT	400-LEVEL CHEMICAL ENGINEERING ELECTIVE			3.0
CHGN/CBEN ELECT	CHGN or CBEN Elective (300 or higher)*			3.0
FREE	FREE ELECTIVE			3.0
FREE	FREE ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-LEVEL RESTRICTED ELECTIVE			3.0
				15.0

Total Semester Hrs: 133.0

TECH Electives

Technical Electives are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement.

CBEN Electives

6 hours are required with 3 hours being at the 400-level.

CBEN250	INTRODUCTION TO CHEMICAL ENGINEERING ANALYSIS AND DESIGN	3.0
CBEN310	INTRODUCTION TO BIOMEDICAL ENGINEERING	3.0
CBEN315	INTRODUCTION TO ELECTROCHEMICAL ENGINEERING	3.0
CBEN340	COOPERATIVE EDUCATION	1-3
CBEN350	HONORS UNDERGRADUATE RESEARCH	1-3
CBEN360	BIOPROCESS ENGINEERING	3.0
CBEN365	INTRODUCTION TO CHEMICAL ENGINEERING PRACTICE	3.0
CBEN372	INTRODUCTION TO BIOENERGY	3.0
CBEN398	SPECIAL TOPICS	1-6
CBEN399	INDEPENDENT STUDY	1-6
CBEN401	PROCESS OPTIMIZATION	3.0
CBEN408	NATURAL GAS PROCESSING	3.0
CBEN409	PETROLEUM PROCESSES	3.0
CBEN415	POLYMER SCIENCE AND TECHNOLOGY	3.0
CBEN416	POLYMER ENGINEERING AND TECHNOLOGY	3.0
CBEN420	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	3.0
CBEN422	CHEMICAL ENGINEERING FLOW ASSURANCE	3.0
CBEN426	ADVANCED FUNCTIONAL POROUS MATERIALS	3.0
CBEN430	TRANSPORT PHENOMENA	3.0
CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN435	INTERDISCIPLINARY MICROELECTRONICS	3.0
CBEN440	MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING	3.0
CBEN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
CBEN480	NATURAL GAS HYDRATES	3.0
CBEN450	HONORS UNDERGRADUATE RESEARCH	1-3
CBEN498	SPECIAL TOPICS	1-6
CBEN499	INDEPENDENT STUDY	1-6

Degree Requirements (Biological Engineering Track)

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
S&W ELECT	SUCCESS & WELLNESS COURSE			1.0
				16.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
CBEN210	INTRO TO THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN200	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING			3.0
CBEN201	MATERIAL AND ENERGY BALANCES			3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
				15.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
CBEN307	FLUID MECHANICS			3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS			3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY			1.0
CHGN428	BIOCHEMISTRY			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
HASS200	GLOBAL STUDIES			3.0
				16.0

Spring		lec	lab	sem.hrs
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER			4.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS			3.0
CBEN403	PROCESS DYNAMICS AND CONTROL			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
CBEN360	BIOPROCESS ENGINEERING			3.0
				16.0

Summer		lec	lab	sem.hrs
CBEN312	UNIT OPERATIONS LABORATORY			3.0
CBEN313	UNIT OPERATIONS LABORATORY			3.0
				6.0

Senior

Fall		lec	lab	sem.hrs
CBEN402	CHEMICAL ENGINEERING DESIGN			3.0
CBEN414	CHEMICAL PROCESS SAFETY			1.0
CBEN418	KINETICS AND REACTION ENGINEERING			3.0
BIO TECH ELECT	BIO TECH ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE II			3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I			4.0
				17.0

Spring		lec	lab	sem.hrs
BIO TECH ELECT	BIO TECH ELECTIVE			3.0
CBEN ELECT	400-LEVEL CHEMICAL ENGINEERING ELECTIVE			3.0
FREE	FREE ELECTIVE			3.0
FREE	FREE ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-LEVEL RESTRICTED ELECTIVE			3.0
				15.0

Total Semester Hrs: 133.0

* The CHGN/CBEN elective course may be any CBEN or CHGN course at the 300-or higher level.

Tech Electives

Technical Electives are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement.

Biological Tech Electives

Six elective credits are required.

BIOL300	INTRODUCTION TO QUANTITATIVE BIOLOGY I	3.0
BIOL301	INTRODUCTION TO QUANTITATIVE BIOLOGY II	3.0
BIOL500	CELL BIOLOGY AND BIOCHEMISTRY	4.0
BIOL510	BIOINFORMATICS	3.0
BIOL520	SYSTEMS BIOLOGY	3.0
CBEN310	INTRODUCTION TO BIOMEDICAL ENGINEERING	3.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN321	INTRO TO GENETICS	4.0
CBEN324	INTRODUCTION TO BREWING SCIENCE	3.0
CBEN372	INTRODUCTION TO BIOENERGY	3.0
CBEN412	INTRODUCTION TO PHARMACOLOGY	3.0
CBEN413	QUANTITATIVE HUMAN BIOLOGY	3.0
CBEN431	IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS	3.0
CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN454	APPLIED BIOINFORMATICS	3.0
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
CHGN409	BIOLOGICAL INORGANIC CHEMISTRY	3.0
CHGN429	BIOCHEMISTRY II	3.0
CHGN431	INTRODUCTORY BIOCHEMISTRY LABORATORY	2.0
CHGN435	PHYSICAL BIOCHEMISTRY	3.0
CHGN441	THE CHEMISTRY AND BIOCHEMISTRY OF PHARMACEUTICALS	3.0
CHGN462	MICROBIOLOGY	3.0
PHGN433	BIOPHYSICS	3.0

400-Level CBEN Electives

CBEN401	PROCESS OPTIMIZATION	3.0
CBEN408	NATURAL GAS PROCESSING	3.0
CBEN409	PETROLEUM PROCESSES	3.0
CBEN415	POLYMER SCIENCE AND TECHNOLOGY	3.0
CBEN416	POLYMER ENGINEERING AND TECHNOLOGY	3.0
CBEN420	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	3.0
CBEN422	CHEMICAL ENGINEERING FLOW ASSURANCE	3.0
CBEN426	ADVANCED FUNCTIONAL POROUS MATERIALS	3.0
CBEN430	TRANSPORT PHENOMENA	3.0
CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN435	INTERDISCIPLINARY MICROELECTRONICS	3.0
CBEN440	MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING	3.0
CBEN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
CBEN480	NATURAL GAS HYDRATES	3.0
CBEN450	HONORS UNDERGRADUATE RESEARCH	1-3

CBEN498	SPECIAL TOPICS	1-6
CBEN499	INDEPENDENT STUDY	1-6

Degree Requirements (Process Engineering Track)

Freshman

Fall		lec	lab	sem.hrs
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
				16.0

Spring		lec	lab	sem.hrs
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
S&W ELECT	SUCCESS & WELLNESS COURSE			1.0
				16.0

Sophomore

Fall		lec	lab	sem.hrs
CBEN210	INTRO TO THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0

Spring		lec	lab	sem.hrs
CBEN200	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING			3.0
CBEN201	MATERIAL AND ENERGY BALANCES			3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
				15.0

Junior

Fall		lec	lab	sem.hrs
CBEN307	FLUID MECHANICS			3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS			3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY			1.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0	4.0
HASS200	GLOBAL STUDIES			3.0
CBEN365	INTRODUCTION TO CHEMICAL ENGINEERING PRACTICE			3.0
				17.0

Spring		lec	lab	sem.hrs
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER			4.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS			3.0
CBEN403	PROCESS DYNAMICS AND CONTROL			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
				16.0

Summer		lec	lab	sem.hrs
CBEN312	UNIT OPERATIONS LABORATORY			3.0
CBEN313	UNIT OPERATIONS LABORATORY			3.0
				6.0

Senior

Fall		lec	lab	sem.hrs
CBEN402	CHEMICAL ENGINEERING DESIGN			3.0
CBEN414	CHEMICAL PROCESS SAFETY			1.0
CBEN418	KINETICS AND REACTION ENGINEERING			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
PROCESS TECH	PROCESS TECH ELECTIVE			3.0
PROCESS TECH	PROCESS TECH ELECTIVE			3.0
				16.0

Spring		lec	lab	sem.hrs
PROCESS ELECT	400-LEVEL PROCESS TECH ELECTIVE			3.0
CHGN/CBEN ELECT	CHGN or CBEN Elective (300 or higher)*			3.0
FREE	FREE ELECTIVE			3.0

FREE	FREE ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-LEVEL RESTRICTED ELECTIVE			3.0
				15.0

Total Semester Hrs: 133.0

* The CHGN/CBEN elective course may be any CBEN or CHGN course at the 300-level or higher.

Tech Electives

Technical Electives are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement.

Process Electives

Students are required to take 9 hours of the follow courses. At least 3 hours must be a 400-level CBEN course.

CBEN372	INTRODUCTION TO BIOENERGY	3.0
CBEN401	PROCESS OPTIMIZATION	3.0
CBEN408	NATURAL GAS PROCESSING	3.0
CBEN409	PETROLEUM PROCESSES	3.0
CBEN422	CHEMICAL ENGINEERING FLOW ASSURANCE	3.0
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
CBEN480	NATURAL GAS HYDRATES	3.0
EBGN453	PROJECT MANAGEMENT	3.0
EBGN553	PROJECT MANAGEMENT	3.0

Degree Requirements (Chemical Engineering Honors Research Track)

Registration into the Honors Research track will be by application only. Applications will be due in the spring semester. The track is designed to fit sophomore-level applicants, though it can also be completed by junior-level students, especially if some research work has already been completed. In addition to the 12 hours of coursework, the following three requirements must be met to earn the Honors Research track. Please see the CBE webpage for additional details.

1) Public dissemination of research work

2) Submission and acceptance of a written undergraduate thesis

3) Complete CBE degree with overall GPA greater than or equal to 3.5

Freshman

Fall		**lec**	**lab**	**sem.hrs**
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
				16.0

Spring		**lec**	**lab**	**sem.hrs**
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
S&W ELECT	SUCCESS & WELLNESS COURSE			1.0
				16.0

Sophomore

Fall		**lec**	**lab**	**sem.hrs**
CBEN210	INTRO TO THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0

Spring		**lec**	**lab**	**sem.hrs**
CBEN200	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING			3.0
CBEN201	MATERIAL AND ENERGY BALANCES			3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
				15.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
CBEN307	FLUID MECHANICS			3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS			3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY			1.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0	4.0
HASS200	GLOBAL STUDIES			3.0
CBEN368	INTRODUCTION TO UNDERGRADUATE RESEARCH			1.0
CBEN350	HONORS UNDERGRADUATE RESEARCH, 351, 450, or 451			2.0
				17.0

Spring		**lec**	**lab**	**sem.hrs**
CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER			4.0

CBEN375	CHEMICAL ENGINEERING SEPARATIONS			3.0
CBEN403	PROCESS DYNAMICS AND CONTROL			3.0
CBEN351	HONORS UNDERGRADUATE RESEARCH, 350, 450, or 451			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
CBEN312	UNIT OPERATIONS LABORATORY			3.0
CBEN313	UNIT OPERATIONS LABORATORY			3.0
				6.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
CBEN402	CHEMICAL ENGINEERING DESIGN			3.0
CBEN414	CHEMICAL PROCESS SAFETY			1.0
CBEN418	KINETICS AND REACTION ENGINEERING			3.0
CBEN430	TRANSPORT PHENOMENA			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) MID-LEVEL RESTRICTED ELECTIVE	3.0		3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CBEN ELECT	500-LEVEL CHEMICAL ENGINEERING ELECTIVE			3.0
TECH	TECH ELECTIVE*			3.0
FREE	FREE ELECTIVE			3.0
FREE	FREE ELECTIVE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-LEVEL RESTRICTED ELECTIVE			3.0
				15.0
Total Semester Hrs: 133.0				

Tech Electives

Technical Electives are any upper division (300-level or higher) in any engineering or science designation. Humanities and Economics courses do not fulfill this requirement.

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- CBEN100 through CBEN599, inclusive

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Biomedical Engineering Minor

To obtain a Biomedical Engineering (BME) minor, students must take at least 18 credits related to Biomedical Engineering. Two courses (8 credits) of biology are required. Two restricted requirements include Intro to Biomedical Engineering (required) and at least 3 credits of engineering electives related to BME. Two more courses (or at least 4 credits) may be chosen from the engineering and/or additional electives. The lists of electives will be modified as new related courses that fall into these categories become available.

REQUIRED courses (11 credits):

CBEN110	FUNDAMENTALS OF BIOLOGY I	4.0
CBEN120	FUNDAMENTALS OF BIOLOGY II	4.0
CBEN310	INTRODUCTION TO BIOMEDICAL ENGINEERING	3.0

Plus at least 3 credits of engineering electives:

BIOL300	INTRODUCTION TO QUANTITATIVE BIOLOGY I	3.0
CBEN35X/45X/X98/X99	HONORS UNDERGRADUATE RESEARCH, SPECIAL TOPICS, INDEPENDENT STUDY *	1-4
CBEN360	BIOPROCESS ENGINEERING	3.0
CBEN413	QUANTITATIVE HUMAN BIOLOGY	3.0
CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
CBEN555	POLYMER AND COMPLEX FLUIDS COLLOQUIUM	1.0
CSCI478	INTRODUCTION TO BIOINFORMATICS	3.0
MATH472	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
or MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT	
MTGN472	BIOMATERIALS I	3.0
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING	3.0
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS	3.0
MEGN537	PROBABILISTIC BIOMECHANICS	3.0

Plus at least 4 more credits from the list above and/or the list below:

Additional elective courses related to BME:

CBEN304	ANATOMY AND PHYSIOLOGY	3.0
CBEN305	ANATOMY AND PHYSIOLOGY LAB	1.0
CBEN311	INTRODUCTION TO NEUROSCIENCE	3.0

CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN321	INTRO TO GENETICS	4.0
CBEN322	BIOLOGICAL PSYCHOLOGY	3.0
CBEN35X/45X/X98/X99	HONORS UNDERGRADUATE RESEARCH, SPECIAL TOPICS, INDEPENDENT STUDY	1-4
CBEN411	NEUROSCIENCE, MEMORY, AND LEARNING (NEUROSCIENCE, MEMORY, AND LEARNING)	3.0
CBEN412	INTRODUCTION TO PHARMACOLOGY (INTRODUCTION TO PHARMACOLOGY)	3.0
CBEN431	IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS	3.0
or CBEN531	IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS	
CBEN454	APPLIED BIOINFORMATICS	3.0
or CBEN554	APPLIED BIOINFORMATICS	
CHGN409	BIOLOGICAL INORGANIC CHEMISTRY	3.0
CHGN428	BIOCHEMISTRY	3.0
CHGN429	BIOCHEMISTRY II	3.0
CHGN441	THE CHEMISTRY AND BIOCHEMISTRY OF PHARMACEUTICALS	3.0
CHGN462	MICROBIOLOGY	3.0
MATH431	MATHEMATICAL BIOLOGY	3.0
MTGN472	BIOMATERIALS I	3.0
or MTGN572	BIOMATERIALS	
PHGN433	BIOPHYSICS	3.0
CHGN431	INTRODUCTORY BIOCHEMISTRY LABORATORY	2.0

*As the content of these courses varies, the course must be noted as relevant to the BME minor to count toward the minor, and noted as having sufficient engineering content to count as an engineering elective course as the engineering electives.

Courses

CBEN110. FUNDAMENTALS OF BIOLOGY I. 4.0 Semester Hrs.
Equivalent with BIOL110,
(I, II) Fundamentals of Biology with Laboratory I. This course will emphasize the fundamental concepts of biology and use illustrative examples and laboratory investigations that highlight the interface of biology with engineering. The focus will be on (1) the scientific method; (2) structural, molecular, and energetic basis of cellular activities; (3) mechanisms of storage and transfer of genetic information in biological organisms; (4) a laboratory 'toolbox' that will carry them forward in their laboratory-based courses. This core course in biology will be interdisciplinary in nature and will incorporate the major themes and mission of this school - earth, energy, and the environment. Lecture Hours: 3; Lab Hours: 3; Semester Hours: 4.
Course Learning Outcomes

- Same as BIOL110

CBEN120. FUNDAMENTALS OF BIOLOGY II. 4.0 Semester Hrs.
Equivalent with CBEN323,
This is the continuation of Fundamentals of Biology I. Emphasis in the second semester is placed on an examination of organisms as the products of evolution and the diversity of life forms. Special attention will be given to how form fits function in animals and plants and the potential for biomimetic applications. Prerequisite: CBEN110. Fundamentals of Biology I or equivalent. 3 hours lecture; 3 hours laboratory; 4 semester hours.
Course Learning Outcomes

- 1. Describe and explain the processes and patterns of evolution, including mutation, variation, and natural selection.
- 2. Describe and explain the properties common within the three domains of life and the innovations that arose in evolutionary time as organisms diversified and adapted to terrestrial environments.
- 3. Use illustrative examples from key animal and plant physiological systems to explain how form fits function in the context of homeostasis and intercellular signaling, development and reproduction, resource acquisition and transport, and to discuss biomimetic and engineering applications of these biological concepts.
- 4. Explain and use the key principles of the scientific process to assess and design experiments.
- 5. Evaluate the credibility of scientific information from various sources.
- 6. Utilize instrumentation and methods for data acquisition and analysis, including tissue preparation for microscopy, dissection and tissue culture.

CBEN198. SPECIAL TOPICS. 6.0 Semester Hrs.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN199. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN200. COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.
Fundamentals of mathematical methods and computer programming as applied to the solution of chemical engineering problems. Introduction to computational methods and algorithm development and implementation. 3 hours lecture; 3 semester hours. Prerequisite: MATH112. Co-requisite: CBEN210.

CBEN201. MATERIAL AND ENERGY BALANCES. 3.0 Semester Hrs.
Equivalent with CHEN201,
Introduction to the formulation and solution of material and energy balances on chemical processes. Establishes the engineering approach to problem solving, the relations between known and unknown process variables, and appropriate computational methods. 3 hours lecture; 3 semester hours. Prerequisite: CHGN122. Co-requisite: CBEN210, CBEN200, MATH213, MATH225.

CBEN202. CHEMICAL PROCESS PRINCIPLES LABORATORY. 1.0 Semester Hr.
Laboratory measurements dealing with the first and second laws of thermodynamics, calculation and analysis of experimental results, professional report writing. Introduction to computer-aided process simulation. 3 hours lab; 1 semester hour. Co-requisite: CBEN210, CBEN201, MATH225, EDNS251.

CBEN210. INTRO TO THERMODYNAMICS. 3.0 Semester Hrs.
Introduction to the fundamental principles of classical engineering thermodynamics. Application of mass and energy balances to closed and open systems including systems undergoing transient processes. Entropy generation and the second law of thermodynamics for closed and open systems. Introduction to phase equilibrium and chemical reaction equilibria. Ideal solution behavior. May not also receive credit

for CHGN209, MEGN261, or GEGN330. Prerequisite: CHGN121, CHGN122, MATH111. Co-requisite: MATH112, PHGN100.

CBEN250. INTRODUCTION TO CHEMICAL ENGINEERING ANALYSIS AND DESIGN. 3.0 Semester Hrs.
Introduction to chemical process industries and how analysis and design concepts guide the development of new processes and products. Use of simple mathematical models to describe the performance of common process building blocks including pumps, heat exchangers, chemical reactors, and separators. Prerequisites: Concurrent enrollment in CBEN210. 3 hours lecture; 3 semester hours.

CBEN298. SPECIAL TOPICS. 1-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN299. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN304. ANATOMY AND PHYSIOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN404,
This course will cover the basics of human anatomy and physiology of the cardiovascular system and blood, the immune system, the respiratory system, the digestive system, the endocrine system, the urinary system and the reproductive system. We will discuss the gross and microscopic anatomy and the physiology of these major systems. Where possible, we will integrate discussions of disease processes and introduce biomedical engineering concepts and problems. Check with department for semester(s) offered. 3 hours lecture; 3 semester hours. Prerequisite: General Biology I.

CBEN305. ANATOMY AND PHYSIOLOGY LAB. 1.0 Semester Hr.
Equivalent with CBEN405,
In this course we explore the basic concepts of human anatomy and physiology using simulations of the physiology and a virtual human dissector program. These are supplemented as needed with animations, pictures and movies of cadaver dissection to provide the student with a practical experience discovering principles and structures associated with the anatomy and physiology. Co-requisite: CBEN404.

CBEN307. FLUID MECHANICS. 3.0 Semester Hrs.
This course covers theory and application of momentum transfer and fluid flow. Fundamentals of microscopic phenomena and application to macroscopic systems are addressed. Course work also includes computational fluid dynamics. 3 hours lecture; 3 semester hours. Prerequisite: MATH225, grade of C- or better in CBEN201.

CBEN308. HEAT TRANSFER. 3.0 Semester Hrs.
This course covers theory and applications of energy transfer: conduction, convection, and radiation. Fundamentals of microscopic phenomena and their application to macroscopic systems are addressed. Course work also includes application of relevant numerical methods to solve heat transfer problems. 3 hours lecture; 3 semester hours. Prerequisite: MATH225, grade of C- or better in CBEN307.

CBEN310. INTRODUCTION TO BIOMEDICAL ENGINEERING. 3.0 Semester Hrs.
Introduction to the field of Biomedical Engineering including biomolecular, cellular, and physiological principles, and areas of specialty including biomolecular engineering, biomaterials, biomechanics, bioinstrumentation and bioimaging. Prerequisite: CBEN110, MATH112.

CBEN311. INTRODUCTION TO NEUROSCIENCE. 3.0 Semester Hrs.
This course is the general overview of brain anatomy, physiology, and function. It includes perception, motor, language, behavior, and executive function. This course will review what happens with injury and abnormalities of thought. It will discuss the overview of brain development throughout one's lifespan. Prerequisite: CBEN110, CHGN121, CHGN122, PHGN100, PHGN200.

CBEN312. UNIT OPERATIONS LABORATORY. 3.0 Semester Hrs.
Unit Operations Laboratory. This course covers principles of mass, energy, and momentum transport as applied to laboratory-scale processing equipment. Written and oral communications skills, teamwork, and critical thinking are emphasized. 9 hours lab; 3 semester hours. Prerequisite: CBEN201, CBEN202 OR CBEN200, CBEN307, CBEN308 OR CBEN314, CBEN357, CBEN375.

CBEN313. UNIT OPERATIONS LABORATORY. 3.0 Semester Hrs.
Unit Operations Laboratory. This course covers principles of mass, energy, and momentum transport as applied to laboratory-scale processing equipment. Written and oral communications skills, teamwork, and critical thinking are emphasized. 9 hours lab; 3 semester hours. Prerequisite: CBEN201, CBEN202 OR CBEN200, CBEN307, CBEN308 OR CBEN314, CBEN357, CBEN375.

CBEN314. CHEMICAL ENGINEERING HEAT AND MASS TRANSFER. 4.0 Semester Hrs.
This course covers theory and applications of energy transfer: conduction, convection, and radiation and mass transfer: diffusion and convection. Fundamentals of microscopic phenomena and their application to macroscopic systems are addressed. Course work also includes application of relevant numerical methods to solve heat and mass transfer problems. Prerequisite: MATH225, CBEN307 with a grade of C- or better. Co-requisite: CBEN200.
Course Learning Outcomes

- Define the basic concepts of heat transfer (e.g. heat flow, heat flux, temperature difference).
- Derive microscopic mass and energy balances for chemical engineering systems.
- Apply Fourier’s law for heat conduction to systems with and without heat source terms and for steady-state and transient operation.
- Solve heat conduction problems involving composite media, standard geometries, and various boundary conditions.
- Apply thermal energy balances together with Newton’s Law of Cooling to convective heat transfer
- Select and apply appropriate convective heat transfer correlations to internal and external flows including boiling and condensation
- Size heat exchangers using the LMTD or NTU method and conduct heat transfer performance calculations using energy balances including identifying controlling resistances for heat exchangers
- Use radiative heat transfer coefficients based on Planck's and Stefan-Boltzmann's laws of radiation for engineering calculations.
- Apply species balances together with Fick’s Law to steady-state and transient diffusion.
- Apply species balances together with relevant rate equations to convective mass transfer.
- Recognize the differences between diffusive and convective mass transfer including diffusion coefficients and mass transfer coefficients. Use correlations to estimate mass transfer coefficients and diffusion coefficients for specified systems and use these to calculate such macroscopic quantities as component fluxes.

- Design continuous mass transfer equipment and analyze its operation.

CBEN315. INTRODUCTION TO ELECTROCHEMICAL ENGINEERING. 3.0 Semester Hrs.
Introduction to the field of Electrochemical Engineering including basic electrochemical principles, electrode kinetics, ionic conduction, as applied to common devices such as fuel cells, electrolyzers, redox flow cells and batteries. 3 hours lecture; 3 semester hours. Prerequisite: CBEN210.
Course Learning Outcomes

- Describe the various principles that are important to Electrochemical engineering, including electrode kinetics and electrocatalysis, double layer capacitance, mass transfer, ionic conduction, Pourbaix diagrams and durability issues, and materials and systems limitations.
- Define the specific areas of specialty in Electrochemical engineering and explain their basic principles (Fuel Cells, Electrolyzers, Batteries, Redox Flow Batteries, Super Capacitors).

CBEN320. CELL BIOLOGY AND PHYSIOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN410,
An introduction to the morphological, biochemical, and biophysical properties of cells and their significance in the life processes. Prerequisite: General Biology I or equivalent.

CBEN321. INTRO TO GENETICS. 4.0 Semester Hrs.
A study of the mechanisms by which biological information is encoded, stored, and transmitted, including Mendelian genetics, molecular genetics, chromosome structure and rearrangement, cytogenetics, and population genetics. 3 hours lecture, 3 hours laboratory; 4 semester hours. Prerequisite: General biology I or equivalent.

CBEN322. BIOLOGICAL PSYCHOLOGY. 3.0 Semester Hrs.
This course relates the hard sciences of the brain and neuroscience to the psychology of human behavior. It covers such topics as decision making, learning, the brain's anatomy and physiology, psychopathology, addiction, the senses, sexuality, and brainwashing. It addresses the topics covered on the psychology section of the MCAT examination. Prerequisite: CBEN110, CHGN122, PHGN200.
Course Learning Outcomes

- Identify the major brain areas and their function.
- Identify microscopic anatomy of cortical layers and columns.
- Describe action potentials, nerve impulses, and networking of brain cells.
- Identify Limbic system components and their part in emotional memory.
- Describe normal and abnormal human behavior.
- Discuss short-term versus long-term memory.
- Describe how explicit and implicit memory work and the differences.
- Describe/compare modern theories of neuroscience and psychology.
- Be able to comprehend current literature (i.e. articles/books) in neuroscience and psychology.
- Describe life span development of the brain, behavior, and social interactions.
- Describe how the brain handles emotion, aggression, and stress.
- Combine the above concepts to discuss the biological foundations of behavior.

CBEN323. GENERAL BIOLOGY II LABORATORY. 1.0 Semester Hr.
Equivalent with CBEN120,
This Course provides students with laboratory exercises that complement lectures given in CBEN303, the second semester introductory course in Biology. Emphasis is placed on an examination of organisms as the products of evolution. The diversity of life forms will be explored. Special attention will be given to the vertebrate body (organs, tissues and systems) and how it functions. Co-requisite or 3 hours laboratory; 1 semester hour. Prerequisite: CBEN303 or equivalent.

CBEN324. INTRODUCTION TO BREWING SCIENCE. 3.0 Semester Hrs.
Introduction to the field of Brewing Science including an overview of ingredients and the brewing process, the biochemistry of brewing, commercial brewing, quality control, and the economics of the brewing industry. Students will malt grain, brew their own beer, and analyze with modern analytical equipment. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisites: CBEN110; Student must be at least 21 years of age at beginning of semester.
Course Learning Outcomes

- Name traditional beer ingredients and the role of each ingredient in the finished product
- Describe the brewing process and the purpose of each step in the brewing process
- Describe the biochemistry of malting, brewing process, fermentation, and beer aging
- Name and describe alternatives to traditional ingredients, process, and fermentation
- Design (with detailed notes) a modern brewing facility
- Describe important characteristics of beer appearance, aroma, flavor, mouthfeel, & stability
- Describe how brewing ingredients, process, and fermentation can be manipulated to affect important beer characteristics
- Formulate a recipe for a BJCP beer style and perform an economic analysis on the recipe in the system designed in 5), above
- Discuss important current topics in brewing

CBEN325. MCAT REVIEW. 3.0 Semester Hrs.
The MCAT Review course is specifically for preparation of the Medical College Admissions Test [MCAT]. It will look at test taking skills, the information required to study for the MCAT, and will go over in detail the psychology information and the critical analysis and reading skills sections of the exam as well as doing practice exams. 3 hours lecture; 3 semester hours. Prerequisite: CBEN110, PHGN200, CHGN222. Co-requisite: CBEN120.
Course Learning Outcomes

- Describe test taking skills.
- Schedule test preparation time over several months.
- Name types of subjects in the MCAT exam.
- Describe important strategies for major testing and exams.
- Use representative concepts from the basic sciences for a more in depth comprehension.
- Describe critical analysis in reading passages.
- Provide specific examples of critical analysis.
- Apply test taking skills to the actual testing format.
- Contrast and compare theories through reading analysis.

CBEN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
Cooperative work/education experience involving employment of a chemical engineering nature in an internship spanning at least

one academic semester. Prerequisite: none. 1 to 3 semester hours. Repeatable to a maximum of 6 hours.

CBEN350. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Scholarly research of an independent nature. Prerequisite: Junior standing. 1 to 3 semester hours.

CBEN351. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Scholarly research of an independent nature. Prerequisite: junior standing. 1 to 3 semester hours.

CBEN357. CHEMICAL ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.
Introduction to non-ideal behavior in thermodynamic systems and their applications. Phase and reaction equilibria are emphasized. Relevant aspects of computer-aided process simulation are incorporated. 3 hours lecture; 3 semester hours. Prerequisite: CBEN210 (or equivalent), MATH225, grade of C- or better in CBEN201.

CBEN358. CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY. 1.0 Semester Hr.
This course includes hands-on laboratory measurements of physical data from experiments based on the principles of chemical engineering thermodynamics. Methods and concepts explored include calculation and analysis of physical properties, phase equilibria, and reaction equilibria and the application of these concepts in chemical engineering. 3 hours lab; 1 semester hour. Prerequisite: CBEN200 and CBEN210 or CHGN209.
Course Learning Outcomes

- Effectively analyze experimental data and generate summary reports of simulation results. This may include solving complicated system of equations or use of optimization techniques.
- Given an experimental objective, design a simple configuration to measure the required data and determine what analysis of the data will be required to obtain the desired information. This includes figuring out what equations need to be applied to the experimentally measured data BEFORE the data is measured. The wet labs may include, as part of the evaluation, building the system into an Aspen model as a means to validate lab results or test the validity of thermodynamic models within Aspen.
- Given a set of measured data, fully analyze the data set and use it to determine associated thermodynamic parameters.

CBEN360. BIOPROCESS ENGINEERING. 3.0 Semester Hrs.
The analysis and design of microbial reactions and biochemical unit operations, including processes used in conjunction with bioreactors, are investigated in this course. Industrial enzyme technologies are developed and explored. A strong focus is given to the basic processes for producing fermentation products and biofuels. Biochemical systems for organic oxidation and fermentation and inorganic oxidation and reduction are presented. Computer-aided process simulation is incorporated. 3 hours lecture; 3 semester hours. Prerequisites: CHGN428, CBEN201, CBEN358.
Course Learning Outcomes

- Describe the growth and decay manipulation of yeast and bacteria, and know what basic cell types are used in / found in various “bioprocess” applications.
- Describe kinetic mechanisms of cell growth and decay, and where appropriate write mathematical models describing the growth processes.
- Draw chemical structures of biological molecules including fats, lipids, amino acids, and proteins.
- Define enzyme and describe mechanistic models for enzyme function; demonstrate a comprehension of Michaelis-Menten and Quasi Steady-State Kinetics by working applied quantitative problems, including aspects of enzyme inhibition. Describe industrial uses of enzyme technologies.
- Summarize and apply the basics of a wide range of “bioprocess” principles such as those of metabolism, biochemical conversion, thermochemical conversion, and direct chemical conversion.
- Describe the basic processes for producing biofuels, fermentation products, and bio-pharmaceuticals by drawing representative process flow diagrams listing the required unit operations.
- Interview successfully for a job in the biochemical process industries by conversing intelligently with the interviewer about technical aspects of biological sciences and biochemical engineering.
- Collect and analyze data for biological processes such as extraction, enzyme kinetics, and aeration.

CBEN365. INTRODUCTION TO CHEMICAL ENGINEERING PRACTICE. 3.0 Semester Hrs.
Builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving approached in an integrated teamwork environment, and initial technical content specific to the Chemical Engineering degree program to solve a range of chemical process engineering problems. Technical content necessary for process analysis and design activity is presented. This course emphasizes steady-state design in areas such as fuels, food sciences, chemicals, and pharmaceuticals, wherein creative and critical thinking skills are necessary. Projects may involve computer-based optimization to obtain a solution. 3 hours lecture; 3 semester hours. Prerequisite: EDNS151 or EDNS155, CBEN 200, CBEN201.
Course Learning Outcomes

- Apply creative and critical thinking skills to chemical engineering projects with an emphasis on process/system designs and data analysis, demonstrated via classroom activities and presentations and through content presented in design reports.
- Analyze design alternatives for a chemical system, identifying best options based on socio-technical-economic design criteria as well as core engineering design criteria, with evidence that supports an optimal design approach, validated using comparative assessment tools (e.g., software tools and design heuristics).
- Actively contribute to design teams, demonstrating commitment to solving open-ended problems through appropriate application of course content/material and incorporating a range of resource management strategies.
- Prepare communication material (presentations and reports) that clearly support engineering design by communicating the technical, economic, and social feasibility of an engineering strategy.

CBEN368. INTRODUCTION TO UNDERGRADUATE RESEARCH. 1.0 Semester Hr.
Introduction to Undergraduate Research. This course introduces research methods and provides a survey of the various fields in which CBE faculty conduct research. Topics such as how to conduct literature searches, critically reading and analyzing research articles, ethics, lab safety, and how to write papers are addressed. Prerequisite: None.

CBEN372. INTRODUCTION TO BIOENERGY. 3.0 Semester Hrs.
In this course the student will gain an understanding about using biological sources and processes for energy uses, both electricity and fuels. There is an emphasis on using chemical engineering principles and tools to aid in the analysis of these bioenergy systems. Specific technologies will be addressed that have historical use and future potential, such as biochemical conversion routes to biofuels (chemical vs. enzymatic hydrolysis followed by fermentation), gasification followed by Fischer-Tropsch synthesis, application of anaerobic digestion, and others. Since products are to be used as energy carriers there will an emphasis on the energy efficiency of transformations and comparing the efficiencies of competing transformation pathways. Prerequisite: CBEN201, CBEN210.
Course Learning Outcomes

- Summarize & discuss the science, engineering, and business fundamentals associated with the bioenergy & biofuels industries
- Analyze the bioenergy industry applying science & engineering fundamentals to feedstocks, conversion technologies, & potential biorefinery configurations
- Specifically apply chemical engineering techniques & process simulation software to analyze bioenergy and biofuel processes

CBEN375. CHEMICAL ENGINEERING SEPARATIONS. 3.0 Semester Hrs.
This course covers fundamentals of stage-wise and diffusional mass transport with applications to chemical engineering systems and processes. Relevant aspects of computer-aided process simulation and computational methods are incorporated. 3 hours lecture; 3 semester hours. Prerequisite: grade of C- or better in CBEN357.

CBEN398. SPECIAL TOPICS. 1-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN399. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN401. PROCESS OPTIMIZATION. 3.0 Semester Hrs.
This course introduces skills and knowledge required to develop conceptual designs of new processes and tools to analyze troubleshoot, and optimize existing processes. Prerequisite: CBEN201, CBEN308 or CBEN314, CBEN307, CBEN357, CBEN375, CBEN402.

CBEN402. CHEMICAL ENGINEERING DESIGN. 3.0 Semester Hrs.
This course covers simulation, synthesis, analysis, evaluation, as well as costing and economic evaluation of chemical processes. Computer-aided process simulation to plant and process design is applied. Prerequisite: CBEN307, CBEN308 or CBEN 314, CBEN357, CBEN375. Co-requisite: CBEN358, CBEN418.

CBEN403. PROCESS DYNAMICS AND CONTROL. 3.0 Semester Hrs.
Mathematical modeling and analysis of transient systems. Applications of control theory to response of dynamic chemical engineering systems and processes. 3 hours lecture; 3 semester hours.Co-requisites: CBEN314 or CBEN308, CBEN375. Prerequisites: CBEN201, CBEN307, MATH225.

CBEN408. NATURAL GAS PROCESSING. 3.0 Semester Hrs.
Application of chemical engineering principles to the processing of natural gas. Emphasis on using thermodynamics and mass transfer operations to analyze existing plants. Relevant aspects of computer-aided process simulation. Prerequisite: CHGN221, CBEN308 or CBEN314, CBEN375.

CBEN409. PETROLEUM PROCESSES. 3.0 Semester Hrs.
Application of chemical engineering principles to petroleum refining. Thermodynamics and reaction engineering of complex hydro carbon systems. Relevant aspects of computer-aided process simulation for complex mixtures. 3 hours lecture; 3 semester hours. Prerequisite: CHGN221, CBEN375.

CBEN411. NEUROSCIENCE, MEMORY, AND LEARNING. 3.0 Semester Hrs.
Equivalent with CBEN511,
This course relates the hard sciences of the brain and neuroscience to memory encoding and current learning theories. 3 hours lecture, 3 semester hours. Prerequisites: CBEN110, CBEN120, CHGN221, CHGN222, PHGN100, PHGN200.

CBEN412. INTRODUCTION TO PHARMACOLOGY. 3.0 Semester Hrs.
This course introduces the concepts of pharmacokinetics and biopharmaceuticals. It will discuss the delivery systems for pharmaceuticals and how they change with disease states. It will cover the modeling of drug delivery, absorption, excretion, and accumulation. The course will cover the different modeling systems for drug delivery and transport. 3 hours lecture; 3 semester hours. Prerequisite: CBEN110, CBEN120, CHGN121, CHGN122.

CBEN413. QUANTITATIVE HUMAN BIOLOGY. 3.0 Semester Hrs.
This course examines the bioelectric implications of the brain, heart, and muscles from a biomedical engineering view point. The course covers human brain, heart, and muscle anatomy as well as the devices currently in use to overcome abnormalities in function. Prerequisite: CBEN 110, CBEN 120.
Course Learning Outcomes

- 1) Describe the mechanisms that make a membrane excitable.
- 2) Order the steps in the production and maintenance of a membrane potential
- 3) Name and define fundamental aspects of brain, heart, and muscle anatomy.
- 4) Describe important roles of the electric components in the brain, heart, and muscle
- 5) Using current monitoring devices, illustrate & compare brain, heart, and muscle recordings.
- 6) Describe critical pathophysiology of the bioelectric systems.
- 7) Provide specific examples of current bioelectrical devices and what they do.
- 8) Describe critical advances in bioelectrical engineering.
- 9) Relate the imaging modalities for the brain and heart as a process of imaging function.
- 10) Describe homeostasis of the bioelectrical pathways by medical intervention.
- 11) Describe how the organs store energy and change the chemical energy into electrical

CBEN414. CHEMICAL PROCESS SAFETY. 1.0 Semester Hr.
This course considers all aspects of chemical process safety and loss prevention. Students are trained for the identification of potential hazards and hazardous conditions associated with the processes and equipment involved in the chemical process industries, and methods of predicting the possible severity of these hazards and presenting, controlling or mitigating them. Quantitative engineering analysis training delivered by each of the CHEN core courses is applied: applications of mass and energy balances, fluid mechanics of liquid, gas, and two-phase flows, heat transfer, the conservation of energy, mass transfer, diffusion

and dispersion under highly variable conditions, reaction kinetics, process control, and statistical analysis. 1 hour lecture; 1 semester hour. Prerequisite: CBEN375. Corequisite: CBEN418.

Course Learning Outcomes

- Students will understand the professional and ethical elements of an outstanding safety program.
- Students will be familiar with government agencies, regulatory bodies, codes, and standards that govern the global, societal, and environmental impact of plant design projects.
- Students will understand how unsound science or unethical behavior had a negative impact on society.
- Students will be able to perform quantitative engineering analysis based upon the applications of mass and energy balance, fluid mechanics of liquid, gas, and two-phase flows, heat transfer and the conservation of energy, mass transfer, diffusion and dispersion under highly variable conditions, reaction kinetics, process control, and statistics.
- Students will be able to work effectively in teams and develop problem solving skills. Each team will prepare and present a professional project report.

CBEN415. POLYMER SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CHGN430,MLGN530,

Chemistry and thermodynamics of polymers and polymer solutions. Reaction engineering of polymerization. Characterization techniques based on solution properties. Materials science of polymers in varying physical states. Processing operations for polymeric materials and use in separations. 3 hours lecture; 3 semester hours. Prerequisite: CHGN222 Co-requisite: CBEN357.

CBEN416. POLYMER ENGINEERING AND TECHNOLOGY. 3.0 Semester Hrs.

Polymer fluid mechanics, polymer rheological response, and polymer shape forming. Definition and measure ment of material properties. Interrelationships between response functions and correlation of data and material response. Theoretical approaches for prediction of polymer properties. Processing operations for polymeric materials; melt and flow instabilities. Prerequisite: CBEN307, MATH225. 3 hours lecture; 3 semester hours.

CBEN418. KINETICS AND REACTION ENGINEERING. 3.0 Semester Hrs.

This course emphasizes applications of the fundamentals of thermodynamics, physical chemistry, organic chemistry, and material and energy balances to the engineering of reactive processes. Key topics include reactor design, acquisition and analysis of rate data, and heterogeneous catalysis. Computational methods as related to reactor and reaction modeling are incorporated. Prerequisite: CBEN308 or CBEN314, CBEN357, MATH225, CHGN221. Co-requisite: CHGN351.

CBEN420. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.

Engineering applications of data analytics and numerical methods, including numerical integration/differentiation, systems of algebraic equations, linear algebra, and ordinary/partial differential equations. Practical implementation in modern programming languages and computational environments discussed. Emphasis on chemical engineering problems that cannot be solved by analytical methods. 3 hours lecture; 3 semester hours. Prerequisite: MATH225, CHGN209 or CBEN210, CBEN307, CBEN357.

CBEN422. CHEMICAL ENGINEERING FLOW ASSURANCE. 3.0 Semester Hrs.

Chemical Engineering Flow Assurance will include the principles of the application of thermodynamics and mesocopic and microscopic tools that can be applied to the production of oil field fluids, including mitigation strategies for solids, including gas hydrates, waxes, and asphaltenes. 3 hours lecture; 3 semester hours. Prerequisite: CBEN357.

Course Learning Outcomes

- 1. Demonstrate an understanding of the chemistry and physical properties of oil field production fluids and solids.
- 2. Demonstrate an understanding of the thermodynamics of oil field fluids and solids, including gas hydrates, waxes, and asphaltenes phase equilibria.
- 3. Be able to apply phase equlibrium models to predict the phase equilibria behavior of complex fluids, as well as gas solubility in water/oil systems.
- 4. Demonstrate an understanding of the macroscopic, mesoscopic, and microscopic tools that can be applied to study oil field processing methods, including the control of hydrates, waxes, asphaltenes, scale.
- 5. Demonstrate an understanding of the appropriate chemical treatments and compatibility of the treatment processes for flow assurance.
- 6. Demonstrate an understanding of the key physical chemistry concepts of flow assurance.
- 7. Demonstrate an understanding of the key concepts of industrial gas transportation and storage.

CBEN424. COMPUTER-AIDED PROCESS SIMULATION. 3.0 Semester Hrs.

Advanced concepts in computer-aided process simulation are covered. Topics include optimization, heat exchanger networks, data regression analysis, and separations systems. Use of industry-standard process simulation software (Aspen Plus) is stressed. 3 hours lecture; 3 semester hours. Prerequisite: CBEN314 or CBEN308, CBEN357, and CBEN375 Co-requisite: CBEN402 and CBEN418.

Course Learning Outcomes

- Modeling Unit Operations
- Modeling Processes Including Recycle Loops
- Process Optimization

CBEN426. ADVANCED FUNCTIONAL POROUS MATERIALS. 3.0 Semester Hrs.

Nanomaterials synthesis, hierarchically ordered porous materials, functional applications, catalysis, separations, adsorption Prerequisite: CHGN122. Co-requisite: CHGN351.

Course Learning Outcomes

CBEN430. TRANSPORT PHENOMENA. 3.0 Semester Hrs.

This course covers theory and applications of momentum, energy, and mass transfer based on microscopic control volumes. Analytical and numerical solution methods are employed in this course. 3 hours lecture; 3 semester hours. Prerequisite: CBEN307, CBEN308 or CBEN314, CBEN357, CBEN375, MATH225.

CBEN431. IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS. 3.0 Semester Hrs.

This course introduces the basic concepts of immunology and their applications in engineering and science. We will discuss the molecular, biochemical and cellular aspects of the immune system including structure and function of the innate and acquired immune systems. Building on this, we will discuss the immune response to infectious agents and the material science of introduced implants and materials such as heart valves, artificial joints, organ transplants and lenses. We will also discuss the role of the immune system in cancer, allergies, immune deficiencies, vaccination and other applications such as immunoassay and flow cytometry. Prerequisite: CBEN110.

CBEN432. TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS. 3.0 Semester Hrs.

The goal of this course is to develop and analyze models of biological transport and reaction processes. We will apply the principles of mass, momentum, and energy conservation to describe mechanisms of physiology and pathology. We will explore the applications of transport phenomena in the design of drug delivery systems, engineered tissues, and biomedical diagnostics with an emphasis on the barriers to molecular transport in cardiovascular disease and cancer. Prerequisite: CBEN307.

CBEN435. INTERDISCIPLINARY MICROELECTRONICS. 3.0 Semester Hrs.

Equivalent with MLGN535,PHGN435,PHGN535,

(II) Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisites: Senior standing in PHGN, CBEN, MTGN, or EGGN. Due to lab, space the enrollment is limited to 20 students. 1.5 hours lecture, 4 hours lab; 3 semester hours.

CBEN440. MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.

Applications of statistical and quantum mechanics to understanding and prediction of equilibrium and transport properties and processes. Relations between microscopic properties of materials and systems to macroscopic behavior. 3 hours lecture; 3 semester hours. Prerequisite: CBEN307, CBEN308 or CBEN314, CBEN357, CBEN375, CHGN351 and CHGN353, CHGN221 and CHGN222, MATH225.

CBEN450. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Scholarly research of an independent nature. Prerequisite: senior standing. 1 to 3 semester hours.

CBEN451. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Scholarly research of an independent nature. Prerequisite: senior standing. 1 to 3 semester hours.

CBEN454. APPLIED BIOINFORMATICS. 3.0 Semester Hrs.

In this course we will discuss the concepts and tools of bioinformatics. The molecular biology of genomics and proteomics will be presented and the techniques for collecting, storing, retrieving and processing such data will be discussed. Topics include analyzing DNA, RNA and protein sequences, gene recognition, gene expression, protein structure prediction, modeling evolution, utilizing BLAST and other online tools for the exploration of genome, proteome and other available databases. In parallel, there will be an introduction to the PERL programming language. Practical applications to biological research and disease will be presented and students given opportunities to use the tools discussed. 3 hour lecture; 3 semester hours. Prerequisites: General Biology [BIOL110].

CBEN455. INTERNATIONAL GENETIC ENGINEERED MACHINE SEMINAR. 1.0 Semester Hr.

iGEM allows for a hands-on experience in the emerging frontier of synthetic biology and genetic engineering while promoting an entrepreneurial spirit as students engage in teams with all aspects of the engineering design process. CBEN455 is a 1-credit hour seminar course that supports the Mines iGEM students in this process through discussions of previous iGEM projects, initial brainstorming of project ideas, discussion of experimental design, training in lab safety and standard molecular biology protocols and team dynamics. The design process starts with stakeholder engagement, and student identification of a problem they wish to solve using synthetic biology. A team will go through the design build test cycle multiple times in preparation for a culminating public presentation at an international symposium. Projects cover frontiers of science and engineering, such as new biochemical production, new materials, environmental projects (e.g., promoting enzymatic degradation of PET plastics), analysis, and health innovations.

Course Learning Outcomes

- Analysis of previous iGEM projects
- Design new iGEM team projects based off literature reviews
- Employ molecular biology lab techniques to answer experimental questions.
- Create a positive team environment that promotes iGEM project success

CBEN460. BIOCHEMICAL PROCESS ENGINEERING. 3.0 Semester Hrs.

The analysis and design of microbial reactions and biochemical unit operations, including processes used in conjunction with bioreactors, are investigated in this course. Industrial enzyme technologies are developed and explored. A strong focus is given to the basic processes for producing fermentation products and biofuels. Biochemical systems for organic oxidation and fermentation and inorganic oxidation and reduction are presented. 3 hours lecture; 3 semester hours Prerequisite: CBEN201, CBEN358, CHGN428.

CBEN461. BIOCHEMICAL PROCESS ENGINEERING LABORATORY. 1.0 Semester Hr.

This course emphasizes bio-based product preparation, laboratory measurement, and calculation and analysis of bioprocesses including fermentation and bio-solids separations and their application to biochemical engineering. Computer-aided process simulation is incorporated. Prerequisites: CBEN375, CHGN428, CHGN462. Co-requisite: CBEN460, 3 hours laboratory, 1 semester hour.

CBEN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with MEGN469,MTGN469,

Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials-science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. 3 hours lecture; 3 semester hours. Prerequisite: MEGN261 or CBEN357.

CBEN470. INTRODUCTION TO MICROFLUIDICS. 3.0 Semester Hrs.

This course introduces the basic principles and applications of microfluidic systems. Concepts related to microscale fluid mechanics, transport, physics, and biology are presented. To gain familiarity with small-scale systems, students are provided with the opportunity to design, fabricate, and test a simple microfluidic device. Prerequisites: CBEN307 or MEGN351. 3 hours lecture; 3 semester hours.

CBEN472. INTRODUCTION TO ENERGY TECHNOLOGIES. 3.0 Semester Hrs.

In this course the student will gain an understanding about energy technologies including how they work, how they are quantitatively evaluated, what they cost, and what is their benefit or impact on the natural environment. There will be discussions about proposed energy systems and how they might become a part of the existing infrastructure. However, to truly understand the impact of proposed energy systems, the student must also have a grasp on the infrastructure of existing energy systems. 3 lecture hours, 3 credit hours. Prerequisite: CBEN357 Chemical Engineering Thermodynamics (or equivalent).

CBEN480. NATURAL GAS HYDRATES. 3.0 Semester Hrs.
The purpose of this class is to learn about clathrate hydrates, using two of the instructor's books, (1) Clathrate Hydrates of Natural Gases, Third Edition (2008) co-authored by C.A.Koh, and (2) Hydrate Engineering, (2000). Using a basis of these books, and accompanying programs, we have abundant resources to act as professionals who are always learning. 3 hours lecture; 3 semester hours.

CBEN498. SPECIAL TOPICS. 1-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN499. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: none, submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

Professors

Sumit Agarwal

Timothy A. Barbari

Anuj Chauhan

Andrew M. Herring

Carolyn A. Koh, William K. Coors Distinguished Chair of Chemical and Biological Engineering

David W. M. Marr, Gaylord & Phyllis Weaver Distinguished Professor, Chemical and Biological Engineering

Amadeu Sum

Colin A. Wolden

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Associate Professors

Nanette R. Boyle, Interim Department Head

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Melissa D. Krebs

Joseph R. Samaniuk

Ning Wu

Assistant Professors

Matthew Crane

Nikki Farnsworth

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Stephanie Kwon

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Teaching Professors

Jason C. Ganley

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Rachel M. Morrish, Associate Department Head

Justin Shaffer, Fryrear Chair

Teaching Associate Professors

Michael D.M. Barankin

Cynthia L. Norrgran

C. Joshua Ramey

Teaching Assistant Professor

Suzannah Beeler

Professor of Practice

John L. Jechura

Professors Emeriti

Robert M. Baldwin

Annette L. Bunge

Anthony M. Dean

James F. Ely, University Professor Emeritus

J. Thomas McKinnon

Ronald L. Miller

E. Dendy Sloan, Jr., University Professor Emeritus

Charles Vestal

J. Douglas Way

Victor F. Yesavage

Civil and Environmental Engineering

Program Description

The Department of Civil and Environmental Engineering (CEE) offers design-oriented and student-centered undergraduate programs in Civil Engineering and Environmental Engineering. The degrees build upon fundamental engineering principles and provide specialization within Civil and Environmental Engineering. Graduates are positioned for a broad range of professional opportunities and are well prepared for an engineering career in a world of rapid technological change.

The Civil Engineering degree offers breadth in several civil engineering fields: Construction Engineering, Engineering Surveying, Environmental

Engineering, Geotechnical Engineering, Structural Engineering, and Water Resources. Civil students can elect to further specialize in one or more of these areas by selecting related courses to fulfill their Civil Engineering Technical Electives.

The Environmental Engineering degree introduces students to the fundamentals of environmental engineering including the scientific and regulatory basis of public health and environmental protection. The degree is designed to prepare students to investigate and analyze environmental systems and assess risks to public health and ecosystems as well as evaluate and design natural and engineered solutions to mitigate risks and enable beneficial outcomes. Topics covered include water reclamation and reuse, hazardous waste management, contaminated site remediation, environmental science, water and wastewater treatment, and regulatory processes.

The Bachelor of Science in Civil Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission's General Criteria and Program Criteria for Civil Engineering.

The Bachelor of Science in Environmental Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission's General Criteria and Program Criteria for Environmental Engineering.

The department also offers two minors and two ASIs. Majors are encouraged to use free elective courses to gain knowledge in another discipline and incorporate either an Area of Special Interest (ASI) or a minor. This adds to the flexibility of the program and qualifies students for a wide variety of careers.

Student Learning Outcomes

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Program Educational Objectives

The Civil Engineering and Environmental Engineering programs contribute to the educational objectives described in the CSM Graduate Profile and the ABET accreditation criteria. Program Educational Objectives (PEOs) of these programs are as follows:

1. Graduates will uphold the standards of Mines as critical and creative innovators, motivators, collaborators, communicators, and leaders.
2. Graduates will be successfully employed in engineering, science, or other impactful careers.
3. Graduates will engage in continual learning by pursuing additional educational opportunities such as advanced degrees, professional licensure, conferences, training, networking, and society membership.
4. Graduates will be ambassadors of their field, contributing to collective knowledge in industry, research, and society.
5. Graduates will demonstrate ethical and responsible behavior in their professional endeavors, adhering to established codes of conduct and promoting the well-being of society and the environment.
6. Graduates will address emerging world challenges by adapting to rapidly evolving technology and industry trends and remaining current and relevant in their respective fields.

Curriculum

During the first two years at Colorado School of Mines, students complete a set of core courses that includes mathematics, basic sciences, and engineering sciences. Coursework in mathematics gives engineering students tools for modeling, analyzing, and predicting physical and chemical phenomena. The basic sciences of physics and chemistry provide an appropriate foundation in the physical sciences; engineering science then builds upon these basic sciences and focuses on applications.

The core curriculum also includes an introduction to engineering design principles and practices. These courses emphasize design methodology and stress the creative and synthesis aspects of the engineering profession. The core curriculum also includes complementary courses in the humanities and social sciences which explore the links between the environment, human society, and engineering.

In the final two years, students complete discipline-specific advanced engineering courses. Civil Engineering students explore soil mechanics, structural theory, design of foundations, design of steel or concrete structures, and Civil Engineering technical electives. Environmental Engineering students explore water chemistry and water quality, air pollution, the fate and transport of chemicals in the environment (air, water, and soil), water resources, environmental policy, and Environmental Engineering technical electives. At the student’s discretion, free electives (9 credits) can be used to either satisfy his/her personal interest in a topic or the credits can be used to pursue an "area of special interest" (12 semester hours) or a minor (at least 18 semester hours). All students complete a capstone engineering design course that is focused on an in-depth, realistic, and multi-disciplinary engineering project.

Students interested in a research experience, in addition to their undergraduate curriculum, are encouraged to work on an Independent Study project with one of the Civil & Environmental Engineering faculty. These projects can offer an applied experience that is relevant to future graduate studies and a professional career.

Bachelor of Science in Civil Engineering Degree Requirements:

Freshman

Fall		lec	lab	sem.hrs
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS or CBEN 110			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				16.0

Spring		lec	lab	sem.hrs
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
S&W	SUCCESS AND WELLNESS			1.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				16.0

Sophomore

Fall		lec	lab	sem.hrs
CEEN210	INTRODUCTION TO CIVIL INFRASTRUCTURE			2.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CEEN241	STATICS			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS200	GLOBAL STUDIES			3.0
				17.0

Spring		lec	lab	sem.hrs
CEEN310	FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING			3.0
CEEN267	DESIGN II: CIVIL ENGINEERING or EDNS 251			3.0
CEEN311	MECHANICS OF MATERIALS			3.0
MATH201	INTRODUCTION TO STATISTICS			3.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CEEN315	CIVIL AND ENVIRONMENTAL ENGINEERING TOOLS			1.0
				16.0

Summer		lec	lab	sem.hrs
CEEN331	ENGINEERING FIELD SESSION, CIVIL			3.0
				3.0

Junior

Fall		lec	lab	sem.hrs
CEEN350	CIVIL AND CONSTRUCTION ENGINEERING MATERIALS			3.0
CEEN314	STRUCTURAL ANALYSIS			3.0
CEEN312	SOIL MECHANICS			3.0
CEEN312L	SOIL MECHANICS LABORATORY			1.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
				16.0

Spring		lec	lab	sem.hrs
CE BREADTH	Civil Engineering Breadth Elective*			3.0
CE BREADTH	Civil Engineering Breadth Elective*			3.0
CEEN415	FOUNDATION ENGINEERING			3.0
STR ELECT	Structural Design Elective**			3.0
MEGN315	DYNAMICS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
				18.0

Senior

Fall		lec	lab	sem.hrs
EDNS491	CAPSTONE DESIGN I			3.0
CE ELECT	Civil Engineering Technical Elective***			3.0
CE ELECT	Civil Engineering Technical Elective***			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective			3.0
FREE	Free Elective			3.0
				18.0

Spring		lec	lab	sem.hrs
EDNS492	CAPSTONE DESIGN II			3.0
CE ELECT	Civil Engineering Technical Elective***			3.0

CE ELECT	Civil Engineering Technical Elective***	3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective	3.0
FREE	Free Elective	3.0
		15.0

Total Semester Hrs: 135.0

***** Civil Engineering Breadth Electives*** - Students must take a minimum of two courses from this list. These courses may count as Civil Engineering Technical Electives or Free Electives if not used to meet this requirement.

CEEN301	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER
CEEN360	INTRODUCTION TO CONSTRUCTION ENGINEERING
CEEN381	HYDROLOGY AND WATER RESOURCES ENGINEERING

***** Structural Design Elective*** - Students must take a minimum of one course from this list. These courses may count as Civil Engineering Technical Electives or Free Electives if not used to meet this requirement.

CEEN443	DESIGN OF STEEL STRUCTURES
CEEN445	DESIGN OF REINFORCED CONCRETE STRUCTURES

****** Civil Engineering Technical Electives*** - Students must take a minimum of four courses from this list. These courses may also count as Free Electives if not used to meet this requirement.

2 Electives must come from a CEEN Prefix:

CEEN302	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: AIR AND WASTE MANAGEMENT
CEEN303	ENVIRONMENTAL ENGINEERING LABORATORY
CEEN401	LIFE CYCLE ASSESSMENT
CEEN402	PROJECT ENGINEERING
CEEN405	NUMERICAL METHODS FOR ENGINEERS
CEEN406	FINITE ELEMENT METHODS FOR ENGINEERS
CEEN410	ADVANCED SOIL MECHANICS
CEEN411	UNSATURATED SOIL MECHANICS
CEEN421	HIGHWAY AND TRAFFIC ENGINEERING
CEEN423	SURVEYING FOR ENGINEERS AND INFRASTRUCTURE DESIGN PRACTICES
CEEN425	CEMENTITIOUS MATERIALS FOR CONSTRUCTION
CEEN426	DURABILITY OF CONCRETE
CEEN430	ADVANCED STRUCTURAL ANALYSIS
CEEN433	MATRIX STRUCTURAL ANALYSIS
CEEN448	STRUCTURAL LOADS
CEEN449	INTRODUCTION TO THE SEISMIC DESIGN OF STRUCTURES
CEEN460	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT
CEEN461	FUNDAMENTALS OF ECOLOGY
CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES
CEEN472	ONSITE WATER RECLAMATION AND REUSE
CEEN473	HYDRAULIC PROBLEMS
CEEN475	HAZARDOUS SITE REMEDIATION ENGINEERING
CEEN478	WATER TREATMENT DESIGN AND ANALYSIS
CEEN479	AIR POLLUTION
CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT
CEEN482	HYDROLOGY AND WATER RESOURCES LABORATORY
CEEN492	ENVIRONMENTAL LAW
GEGN466	GROUNDWATER ENGINEERING
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS
GEGN473	GEOLOGICAL ENGINEERING SITE INVESTIGATION
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS
MEGN416	ENGINEERING VIBRATION
MNGN321	INTRODUCTION TO ROCK MECHANICS
MNGN404	TUNNELING
MNGN405	ROCK MECHANICS IN MINING
MNGN406	DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

CEEN100 through CEEN499 inclusive

Bachelor of Science in Environmental Engineering Degree Requirements:

Freshman

Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
HASS100	NATURE AND HUMAN VALUES			3.0

CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				16.0

Spring		lec	lab	sem.hrs
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				16.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CEEN241	STATICS			3.0
EDNS251	CORNERSTONE DESIGN II or CEEN 267			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				15.0

Spring		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
CEEN301	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER			3.0
CEEN310	FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING			3.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
HASS200	GLOBAL STUDIES			3.0
				15.0

Junior

Fall		lec	lab	sem.hrs
CEEN381	HYDROLOGY AND WATER RESOURCES ENGINEERING			3.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS, CBEN 210, or MEGN 261			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
MATH201	INTRODUCTION TO STATISTICS			3.0
				15.0

Spring		lec	lab	sem.hrs
CEEN302	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: AIR AND WASTE MANAGEMENT			3.0
CEEN303	ENVIRONMENTAL ENGINEERING LABORATORY			3.0
BIOSCI ELECT	Bio-Science Elective*			3.0
EVE ELECT	Environmental Engineering Elective**			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective			3.0
				18.0

Summer		lec	lab	sem.hrs
CEEN330	ENGINEERING FIELD SESSION, ENVIRONMENTAL			3.0
				3.0

Senior

Fall		lec	lab	sem.hrs
EDNS491	CAPSTONE DESIGN I			3.0
CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES			3.0
CEEN482	HYDROLOGY AND WATER RESOURCES LABORATORY			3.0
EVE ELECT	Environmental Engineering Elective**			3.0
EVE ELECT	Environmental Engineering Elective**			3.0
FREE	Free Elective			3.0
				18.0

Spring		lec	lab	sem.hrs
EDNS492	CAPSTONE DESIGN II			3.0
CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT			3.0
EVE ELECT	Environmental Engineering Elective**			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
FREE	Free Elective			3.0
				15.0

Total Semester Hrs: 131.0

**** Bio-science Elective Courses -*** Students must take a minimum of one course from this list. If this requirement is met with BIOL110, then CEEN460, CEEN461 and CHGN462 may count as Environmental Engineering Electives or Free Electives. BIOL110 cannot count as an Environmental Engineering Elective.

CBEN110	FUNDAMENTALS OF BIOLOGY I
CEEN460	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT
CEEN461	FUNDAMENTALS OF ECOLOGY
CHGN462	MICROBIOLOGY

***** Environmental Engineering Elective Courses -** Students must take a minimum of four courses from this list. These courses may count as Free Electives if not used to meet this requirement.

CEEN311	MECHANICS OF MATERIALS
CEEN312	SOIL MECHANICS
CEEN405	NUMERICAL METHODS FOR ENGINEERS
CEEN401	LIFE CYCLE ASSESSMENT
CEEN402	PROJECT ENGINEERING
CEEN410	ADVANCED SOIL MECHANICS
CEEN425	CEMENTITIOUS MATERIALS FOR CONSTRUCTION
CEEN426	DURABILITY OF CONCRETE
CEEN460	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT
CEEN461	FUNDAMENTALS OF ECOLOGY
CEEN472	ONSITE WATER RECLAMATION AND REUSE
CEEN473	HYDRAULIC PROBLEMS
CEEN475	HAZARDOUS SITE REMEDIATION ENGINEERING
CEEN478	WATER TREATMENT DESIGN AND ANALYSIS
CEEN479	AIR POLLUTION
CEEN492	ENVIRONMENTAL LAW
CEEN555	LIMNOLOGY
CEEN581	WATERSHED SYSTEMS MODELING
CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY
CHGN462	MICROBIOLOGY
ENGY320	INTRO TO RENEWABLE ENERGY
GEGN466	GROUNDWATER ENGINEERING
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS
GEGN473	GEOLOGICAL ENGINEERING SITE INVESTIGATION
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS
MEGN467	PRINCIPLES OF BUILDING SCIENCE
PEGN430	ENVIRONMENTAL LAW AND SUSTAINABILITY

Major GPA

During the 2016-2017 Academic Year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree’s GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree’s GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

CEEN300 through CEEN499 inclusive

Bachelor of Science in Construction Engineering Degree Requirements:

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1) or 125			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				16.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
CEEN210	INTRODUCTION TO CIVIL INFRASTRUCTURE			2.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CEEN241	STATICS			3.0
HASS200	GLOBAL STUDIES			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CEEN267	DESIGN II: CIVIL ENGINEERING			3.0
CEEN311	MECHANICS OF MATERIALS			3.0
CEEN360	INTRODUCTION TO CONSTRUCTION ENGINEERING			3.0
MATH201	INTRODUCTION TO STATISTICS			3.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0

Summer		lec	lab	sem.hrs
CEEN331	ENGINEERING FIELD SESSION, CIVIL			3.0
				3.0

Junior

Fall		lec	lab	sem.hrs
CEEN312	SOIL MECHANICS			3.0
CEEN312L	SOIL MECHANICS LABORATORY			1.0
CEEN314	STRUCTURAL ANALYSIS			3.0
CEEN350	CIVIL AND CONSTRUCTION ENGINEERING MATERIALS			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
CEENXXX	CONSTRUCTION ENGINEERING MEANS & METHODS Prereq: CEEN360			3.0
				16.0

Spring		lec	lab	sem.hrs
CEENXXX	CONSTRUCTION ESTIMATING, PLANNING AND SCHEDULING Prereq:CEEN360			3.0
CEENXXX	CONSTRUCTION PROJECT ADMINISTRATION AND CONTROLS			3.0
CEEN415	FOUNDATION ENGINEERING			3.0
EBGN321	ENGINEERING ECONOMICS *For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
CAS MID-LEVEL ELECTIVE				3.0
TECHNICAL ELECTIVE	CEEN421, CEEN423, CEEN425, CEEN443, CEEN445, CEEN477, CEEN381 (PREREQ: CEEN310)			3.0
				18.0

Senior

Fall		lec	lab	sem.hrs
EDNS491	CAPSTONE DESIGN I			3.0
CEENXXX	INTEGRATED DESIGN AND CONSTRUCTION I Prereqs: CONSTRUCTION PROJECT ADMINISTRATION AND CONTROLS (CPAC), CONSTRUCTION ESTIMATING, PLANNING, AND SCHEDULING (CEPS)			3.0
CEENXXX	CONSTRUCTION LAW Prereq: CEEN360			3.0
CAS MID-LEVEL ELECTIVE				3.0
TECHNICAL ELECTIVE	CEEN421, CEEN423, CEEN425, CEEN443, CEEN445, CEEN477, CEEN381 (prereq: CEEN310)			3.0
TECHNICAL ELECTIVE	CEEN421, CEEN423, CEEN425, CEEN443, CEEN445, CEEN477, CEEN381 (prereq: CEEN310)			3.0
				18.0

Spring		lec	lab	sem.hrs
EDNS492	CAPSTONE DESIGN II			3.0
CEENXXX	INTEGRATED DESIGN AND CONSTRUCTION II Prereq: INTEGRATED DESIGN AND CONSTRUCTION I			3.0
CAS MID-LEVEL ELECTIVE				3.0
FREE ELECTIVE				3.0
FREE ELECTIVE				3.0
				15.0

Total Semester Hrs: 134.0

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Civil or Environmental Engineering Minor and ASI

ASI in Civil Engineering

Civil engineering is a closely related field to many majors on campus, including mechanical engineering, electrical engineering, petroleum engineering, geological engineering, and mining engineering. A background in civil engineering fundamentals bolsters students' credentials for careers in the construction industry, the mining industry, the energy sector, or public policy, and service. This Area of Special Interest (ASI) has been carefully designed to introduce the fundamentals of the major subfields of civil engineering at Mines: structural engineering, geotechnical engineering, water resources and hydrology, environmental engineering, construction engineering, and surveying.

Students are encouraged to explore other courses relevant to this ASI and propose their own plan of study that would support the Area of Special Interest- Civil Engineering. For preapproval on potential course substitutions to fulfill this ASI, please contact the undergraduate program manager for Civil/Environmental Engineering.

Four courses (12 credits) are required for this ASI.

Required		6.0
CEEN312	SOIL MECHANICS	
CEEN314	STRUCTURAL ANALYSIS	
Electives (See List)		6.0
Total Semester Hrs		**12.0**

Elective List: Select two of the following four courses:

CEEN301	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER	3.0
CEEN331	ENGINEERING FIELD SESSION, CIVIL	3.0

CEEN360	INTRODUCTION TO CONSTRUCTION ENGINEERING	3.0
CEEN381	HYDROLOGY AND WATER RESOURCES ENGINEERING	3.0

Students who are majoring in Civil Engineering cannot complete this ASI. A student majoring in Environmental Engineering can complete this ASI by completing CEEN312, CEEN314, CEEN331, and CEEN360. Courses cannot be double counted as Environmental Engineering electives. Up to three of these courses may be double counted toward the BS Environmental Engineering as free electives. This requirement ensures that there is sufficient distinction between the degree and the minor.

ASI in Environmental Engineering

Environmental engineering is at the forefront of solving the world's challenges related to earth, energy and environment. As such, an ability to apply environmental fundamentals to engineering practice within disciplines such as geological, mining, electrical, computational, mechanical, petroleum, and chemical processing industries as well as public policy and service bolsters students' credentials in those fields. This Area of Special Interest (ASI) has been carefully designed to introduce the fundamentals of environmental engineering at Mines: environmental science and chemistry, hydrology and water resources, water and wastewater treatment, chemical implications, and fate and transport to enable an understanding and application of these themes to practitioners across disciplines.

Students are encouraged to explore other courses relevant to this minor and propose their own plan of study that would support this Area of Special Interest (ASI). For preapproval on potential course substitutions to fulfill this ASI, please contact the undergraduate program manager for Civil/Environmental Engineering.

Four courses (12 credits) are required for this ASI.

Complete 4 of the following 5 courses:		12.0
CEEN301	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER	
CEEN302	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: AIR AND WASTE MANAGEMENT	
CEEN381	HYDROLOGY AND WATER RESOURCES ENGINEERING	
CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES	
CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	

Students who are majoring in Environmental Engineering cannot complete this ASI. A student majoring in Civil Engineering can only earn this ASI by completing all five of the courses (15 credits total). Of those five courses, only two may be double counted toward the major degree requirements. This additional requirement is necessary in order to ensure sufficient distinction between the degree and the ASI.

Minor in Structural Engineering

Structural engineering services are in high demand in virtually every engineering industry, spanning from construction to manufacturing to aerospace. This minor has been developed for students with an interest in the principles of solid mechanics who wish to learn how to design structures in practical applications. Topics covered in this minor include various methods and theories for structural analysis and design; finite-element methods; design with steel, concrete, timber, and masonry; and an introduction to the seismic design of structures.

Students are encouraged to explore other courses relevant to this minor and propose their own plan of study that would support the Structural minor. For preapproval on potential course substitutions to fulfill this minor, please contact the undergraduate program manager for Civil/Environmental Engineering.

Six courses (18 credits) are required for this minor.

Required		**3.0**
CEEN314	STRUCTURAL ANALYSIS [1]	
Electives (See List)		**15.0**
Total Semester Hrs		**18.0**

Elective List: Select five of the following seven courses:

CEEN406	FINITE ELEMENT METHODS FOR ENGINEERS
CEEN430	ADVANCED STRUCTURAL ANALYSIS
CEEN433	MATRIX STRUCTURAL ANALYSIS
CEEN442	DESIGN OF WOOD STRUCTURES
CEEN443	DESIGN OF STEEL STRUCTURES
CEEN445	DESIGN OF REINFORCED CONCRETE STRUCTURES
CEEN449	INTRODUCTION TO THE SEISMIC DESIGN OF STRUCTURES

In order to ensure sufficient distinction between the degree and the minor, Civil Engineering students must meet additional requirements to earn this minor. Courses that are required for the degree (CEEN314 and either CEEN443 or CEEN445) may not be double counted toward the minor. Therefore, the remaining six courses on the list must be taken in order to earn the minor (CEEN406, CEEN430, CEEN442, CEEN443/CEEN445, CEEN433, CEEN449). None of the six courses may be double counted as Civil Engineering technical electives, but a maximum of three may be double counted as free electives. The remaining courses used for the minor may not be applied to the BS Civil degree.

Students may also propose the substitution of other CEEN-prefixed structural engineering courses, such as 500-level graduate courses or approved special topics courses with approval of the department.

[1]The prerequisite to CEEN314, Structural Analysis, is CEEN311 Mechanics of Materials. Students who have completed MEGN 312 Introduction to Solid Mechanics are encouraged to pursue a prerequisite override.

Minor in Water Sustainability

Assuring safe and sustainable water supplies is one of the world's most pressing challenges. Understanding the design and implementation of water systems and related infrastructure requires diverse knowledge within the water resources field but that knowledge also crosses into numerous engineering disciplines. Students who are pursuing careers in the mining industry, energy industry, manufacturing industry, chemical processing industry, and public policy sector can bolster their credentials with this minor. The Water Sustainability minor has been developed to expose students to the relevant subfields of water and environmental systems, including water chemistry, fluid mechanics, water resources and hydrology, fate and transport of chemicals in the environment, site remediation, and onsite water reclamation and reuse.

Students are encouraged to explore other courses relevant to this minor and propose their own plan of study that would support the Water Sustainability minor. For preapproval on potential course substitutions to fulfill this minor, please contact the undergraduate program manager for Civil/Environmental Engineering.

Six courses (18 credits) are required for this minor.

Required Courses		**12.0**
CEEN301	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER	
CEEN310	FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING [1]	
CEEN381	HYDROLOGY AND WATER RESOURCES ENGINEERING	
CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES	
Electives (See List)		**6.0**
Total Semester Hrs		**18.0**

Elective List: Select two of the following six courses:

CEEN472	ONSITE WATER RECLAMATION AND REUSE
CEEN475	HAZARDOUS SITE REMEDIATION ENGINEERING
CEEN478	WATER TREATMENT DESIGN AND ANALYSIS
CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT
CEEN482	HYDROLOGY AND WATER RESOURCES LABORATORY

Civil Engineering and Environmental Engineering majors may not pursue this minor, as there is too much overlap between degree requirements and the minor. The combined (BS/MS) degree program may be a suitable option for Civil or Environmental majors that wish to focus in Sustainable Water Engineering.

[1] Students who have completed a different variation of a fluid mechanics are encouraged to pursue a course substitution request so that the completed course can be double-counted for the minor.

Courses

CEEN198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CEEN210. INTRODUCTION TO CIVIL INFRASTRUCTURE. 2.0 Semester Hrs.
An introduction to civil infrastructure systems, including the analysis, design and management of infrastructure that supports human activity, including transportation (road, rail, aviation), water and wastewater, communications and power.

CEEN241. STATICS. 3.0 Semester Hrs.
Forces, moments, couples, equilibrium, centroids and second moments of areas, volumes and masses, hydrostatics, and friction. Applications of vector algebra to structures. 3 hours lecture; 3 semester hours. Prerequisite: PHGN100 and credit or concurrent enrollment in MATH112.

CEEN267. DESIGN II: CIVIL ENGINEERING. 3.0 Semester Hrs.
Equivalent with EPIC267,
Design II builds on the design processes introduced in Design I, focusing on open-ended problem solving in which students integrate teamwork and communication with the use of computer software, AutoCAD and Civil3D, as tools to solve engineering problems. Projects often include planning, due diligence, construction document preparation, and site certification processes in the context of land development projects. Prerequisite: EDNS151 or EDNS155 or EDNS192 or HNRS115 or Grandey First-Year Honors Experience (HNRS198A and HNRS198B.

CEEN298. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CEEN301. FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER. 3.0 Semester Hrs.
This course introduces fundamentals of environmental science & engineering as applied to water resource management and environmental problem solving. Topics include environmental regulation, toxicology, material balance, applications in environmental chemistry, hydrology, water quality management, water supply and treatment, and wastewater treatment and reuse. Topical discussions will address major sources and concerns in measurement, practice and underlying theory in the field of environmental engineering. The course also includes field trips to local water and wastewater treatment facilities to integrate theory with practice. 3 hours lecture; 3 semester hours. Prerequisite: CHGN122, PHGN100.

CEEN302. FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: AIR AND WASTE MANAGEMENT. 3.0 Semester Hrs.
Introductory level fundamentals in atmospheric systems, air pollution control, solid waste management, hazardous waste management, waste minimization, pollution prevention, role and responsibilities of public institutions and private organizations in environmental management (relative to air, solid and hazardous waste). 3 hours lecture; 3 semester hours. Prerequisite: CHGN122, PHGN100 and MATH213 or consent of instructor.

CEEN303. ENVIRONMENTAL ENGINEERING LABORATORY. 3.0 Semester Hrs.
Equivalent with ESGN355,
This course introduces the laboratory and experimental techniques used for generating and interpreting data in environmental science

and engineering related to water, land, and environmental health. An emphasis is placed on quantitative chemical and microbiological analysis of water and soil samples relevant to water supply and wastewater discharge. Topics include basic water quality measurements (pH, conductivity, etc.) and quantitative analysis of chemicals by chromatographic and mass spectrometric techniques. Advanced topics include quantitative and qualitative analysis of bioreactor performance, bench testing for water treatment, and measurement and control of disinfection by-products. Prerequisite: CEEN301 or CEEN302.

CEEN310. FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING. 3.0 Semester Hrs.

The study and application of principles of incompressible fluid mechanics. Topics include: hydrostatic forces on submerged surfaces, buoyancy, control volume analysis, conservation of mass, fluid motion, Bernoulli's equation and conservation of energy, momentum, dimensional analysis, internal flow (pipe systems), external flow (drag and lift), flow in open channels, and hydraulic jumps. The course will also introduce concepts about municipal water supply networks and storm water drainage and wastewater collection and treatment systems. May not also receive credit for PEGN251 or MEGN351. Prerequisites: PHGN100, CEEN241. 3 lecture hours, 3 semester hours.

Course Learning Outcomes

- Distinguish what physical aspects of fluid flow are most critical and have the greatest impact on a given problem and design.
- Establish an intuition for fluid behavior, analyze its effects in a given problem, and apply knowledge to propose design solutions.
- Leverage improved proficiency in critical thinking skills, technical writing skills, and oral communication skills.
- Calculate pressure forces on submerged surfaces and explain and apply measurement of pressures (fluid statics).
- Apply differential conservation-of-mass and linear-momentum equations and material derivatives to the solution of flow problems.
- Model laminar and turbulent pipe flow systems.
- Design and size pumps for system requirements.
- Explain the concepts of open-channel flow as found in rivers and fluid conduits and sewer and storm sewer design.
- Derive and solve mass conservation, momentum, and energy equations for steady-state fluid-flow systems, including open-channel flows (control-volume analyses).

CEEN311. MECHANICS OF MATERIALS. 3.0 Semester Hrs.

Fundamentals of stress, strain, deformation, and material properties. Mechanics of members subjected to axial, torsional, bending, and combined loads; beam deflection; static indeterminacy; Euler buckling; stress transformation and principal stresses; thermal stress, strain, and deformation; thin-walled pressure vessels; Allowable Stress Design; and stress concentrations. May not also receive credit for MEGN212. Prerequisite: CEEN241.

CEEN312. SOIL MECHANICS. 3.0 Semester Hrs.

An introductory course covering the engineering properties of soil, soil phase relationships and classification. Principle of effective stress. Seepage through soils and flow nets. Soil compressibility, consolidation and settlement prediction. Shear strength of soils. 3 hours lecture; 3 semester hours. Prerequisite: CEEN311.

CEEN312L. SOIL MECHANICS LABORATORY. 1.0 Semester Hr.

Introduction to laboratory testing methods in soil mechanics. Classification, permeability, compressibility, shear strength. 3 hours lab; 1 semester hour. Co-requisite: CEEN312.

CEEN314. STRUCTURAL ANALYSIS. 3.0 Semester Hrs.

Analysis of determinate and indeterminate structures for both forces and deflections. Influence lines, work and energy methods, moment distribution, matrix operations, computer methods. 3 hours lecture; 3 semester hours. Prerequisite: CEEN311.

CEEN315. CIVIL AND ENVIRONMENTAL ENGINEERING TOOLS. 1.0 Semester Hr.

Students in this project-based course will be introduced to and implement useful, industry standard tools from Civil and Environmental Engineering fields. Although unlimited, subjects presented may include: introduction to industry software, data analysis, materials testing, design preparation/presentation, or hands-on exercises illustrating concepts presented in lecture. Content will be presented in modules that occur over three to five-week periods. Modules indicative of the breadth of the profession will be offered. Credit hours will be awarded based on the completion of least three modules encompassing 15 weeks. Co-requisite: CEEN310, CEEN311.

Course Learning Outcomes

- Analyze data to help draw conclusions and drive decisions.
- Demonstrate competency and understanding of industry-based practices including such content as lab procedures or design software.
- Solve engineering problems using engineering tools to formulate conclusions.
- Develop a knowledge base surrounding industry practice.
- Validate equations and models learned in lecture through lab/field exercises.

CEEN330. ENGINEERING FIELD SESSION, ENVIRONMENTAL. 3.0 Semester Hrs.

The environmental module is intended to introduce students to laboratory and field analytical skills used in the analysis of an environmental engineering problem. Students will receive instruction on the measurement of water quality parameters (chemical, physical, and biological) in the laboratory and field. The student will use these skills to collect field data and analyze a given environmental engineering problem. Three weeks in summer session. 9 hours lab; 3 semester hours. Prerequisite: CEEN301, CEEN303.

CEEN331. ENGINEERING FIELD SESSION, CIVIL. 3.0 Semester Hrs.

The theory and practice of modern surveying. Lectures and hands-on field work teaches horizontal, vertical, and angular measurements and computations using traditional and modern equipment. Subdivision of land and applications to civil engineering practice, GPS and astronomic observations. Three weeks (6 day weeks) in summer field session; 9 hours lab; 3 semester hours. Prerequisite: EDNS251, CEEN267.

CEEN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I,II,S) Supervised full-time engineering-related employment in which specific educational objectives are set and achieved. The co-op differs from a typical internship in both the length and scope of responsibilities. Students must meet with the CEE Co-op Advisor prior to enrolling to determine the appropriateness of the engagement, clarify the educational objectives, set expectations, and receive written approval for their specific Co-op program. This prior approval of the CEE Co-op Advisor and completion of paperwork with the Career Center is required prior to beginning the work portion of the program. The co-op occurs during academic fall or spring semester(s) and may overlap with a summer session, with a typical length of six months total. 3.0 credit hours. This course is repeatable. Prerequisite: Second semester sophomore status or above and a cumulative grade-point average of at least 2.00.

CEEN350. CIVIL AND CONSTRUCTION ENGINEERING MATERIALS. 3.0 Semester Hrs.

This course deals with the nature and performance of civil engineering materials and evaluation of their physical and mechanical properties. This course focuses on materials used in construction and maintenance of building and infrastructure such as metals (steel and aluminum), aggregates, Portland cement, concrete, shotcrete, asphalt, wood, recycled materials, and composites. The course covers standards describing materials and tests for determining material properties and includes a lab component where students conduct tests, analyze the resulting data, and prepare technical reports. Laboratory tests include evaluation of behavior of civil engineering materials under a wide range of conditions. 2 hours lecture; 3 hours lab, 3 semester hours. Prerequisite: CEEN311.

Course Learning Outcomes

- Describe the basic properties of a variety of civil engineering materials including metals, concrete, aggregates, asphalt, and wood.
- Identify and explain significant considerations in choosing a material for a specific application including, for example, mechanical properties, durability, and sustainability.
- Follow standards to conduct tests of material properties and perform the calculations necessary to analyze and interpret test results.
- Explain the importance of standards in the context of civil engineering materials.
- Work effectively in teams to perform experimental tasks.
- Write formal technical report and convey engineering message efficiently.
- Use commercial engineering test equipment to determine mechanical properties of engineering materials.
- Design and make conventional and high performance Portland cement concrete mixtures and evaluate their fresh and hardened properties.
- Apply the field quality control procedures in the manufacturing and placing of Portland cement concrete and hot-mix asphalt

CEEN360. INTRODUCTION TO CONSTRUCTION ENGINEERING. 3.0 Semester Hrs.

(II) Overview of the construction process for civil construction (spanning the building, transportation, and infrastructure sectors), including procurement methods and project delivery methods, codes, regulations, tests, standards, and Risk estimation and management. Construction methods and materials. Construction contracts, including drawings and specifications. Construction administration, including submittals, requests for information, change orders, special instructions, claims, disputes, arbitration, litigation, and project close-out. Project scheduling using the Critical Path Method. Construction project management. Construction safety and OSHA. Quantity takeoffs and construction estimating. Application of engineering analysis and design to construction projects. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Explain and describe common construction processes and procedures; compare procurement methods and project delivery methods.
- Describe the engineering decision#making process for selection of various construction materials and systems; choose appropriate construction materials and assemblies for a given set of constraints; apply engineering criteria to compare various construction means and methods for a given set of constraints.
- Analyze a professional set of construction documents, including the front#end documents, general conditions, supplementary conditions, drawings, and specifications.
- Write a construction specification section.
- Perform quantity take#offs and estimates using hand methods and software analysis.
- Design and optimize a schedule for a construction project using the Critical Path Method.
- Explain common construction administration activities, such as submittal review, requests for information, change orders, special instructions, claims and disputes, litigation and arbitration, and project close#out procedures.
- Analyze OSHA requirements for construction safety and apply those requirements to a construction project.

CEEN381. HYDROLOGY AND WATER RESOURCES ENGINEERING. 3.0 Semester Hrs.

Equivalent with CEEN481,ESGN459,

This course introduces the principles of physical hydrology and fundamentals of water resources engineering. Topics include groundwater, surface water, precipitation, infiltration, evapotranspiration, sediment transport, flood and drought analysis, lake and reservoir analysis, water-resources planning, water quality engineering, stormwater management, and engineering design problems. 3 hour lecture; 3 semester hours. Prerequisite: CEEN310.

CEEN398. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN399. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Variable credit; 1 to 6 credit hours. Repeatable for credit. Prerequisite: Independent Study form must be completed and submitted to the Registrar.

CEEN401. LIFE CYCLE ASSESSMENT. 3.0 Semester Hrs.

Which is more sustainable: paper vs plastic, hybrid vs electric vehicles? LCA is a powerful tool used to answer these questions; LCA quantifies the environmental sustainability of a product or process. Students will learn to conduct an LCA during a semester-long project of their choosing. At the end of the course students should be able to sit for the ACLCA professional LCACP certification exam. Prerequisite: Junior standing.

Course Learning Outcomes

- 1. Identify environmental sustainability challenges and opportunities for engineered systems from a life-cycle perspective
- 2. Draw a process flow diagram and Create a life cycle inventory
- 3. Understand and calculate different environmental impact categories
- 4. Conduct a simple life cycle assessment for a product or process
- 5. Utilize LCA results for decision making
- 6. Understand the process for conducting an ISO 14000 series certified LCA

CEEN402. PROJECT ENGINEERING. 3.0 Semester Hrs.

Project Engineers - through their "big picture" understanding of overall project completion requirements, technical knowledge of the components that have to be coordinated & assembled, and application of people skills - get things done. This career-oriented course focuses on the roles & responsibilities, skills, and character of the Project Engineer as a problem-solver, integrator, and leader. Content, procedural, and relationship project needs essential for project execution success are identified. Practical instruction and exercises are given - formulated around industry documents and templates - on key project execution best practices such as estimating (cost, weight, etc.), scheduling, quality, earned value, constructability, risk management, and root-cause analysis. Emotional Intelligence is introduced along with identification of skills that are essential for leading projects and people to success. Management, leadership, and ethical principles and best practices are illustrated through case studies of complex, high-profile domestic and international projects. Prior to taking the course, design and analysis courses along with any project/construction management experience beneficial but not expected. Courses recommended concurrently include courses equivalent to CEEN591, CEEN594, EBGN553, and MNGN509 are advantageous but not required. 3 hours lecture; 3 semester hours. Prerequisite: CEEN360.

Course Learning Outcomes

- Differentiate the unique roles & responsibilities and skill set requirements of a Project Engineer
- Organize a Work Breakdown Structure, use it as a basis for developing estimates for cost and schedule, and critically assess project progress by calculating Earned Value
- Develop a simple project schedule using manual Arrow-on-Node and electronic Microsoft Project methods; propose schedule compression options and their impact on a troubled project
- Develop a simple Constructability Register with a fundamental understanding of engineer vs. constructor motivations
- Develop a simple Risk Register, Risk Matrix, and Risk Mitigation Plan
- Identify the management and emotional skills that enable a Project Engineer to achieve effective project delivery and personal integrity and success

CEEN405. NUMERICAL METHODS FOR ENGINEERS. 3.0 Semester Hrs.

Introduction to the use of numerical methods in the solution of problems encountered in engineering analysis and design, e.g. linear simultaneous equations (e.g. analysis of elastic materials, steady heat flow); roots of nonlinear equations (e.g. vibration problems, open channel flow); eigenvalue problems (e.g. natural frequencies, buckling and elastic stability); curve fitting and differentiation (e.g. interpretation of experimental data, estimation of gradients); integration (e.g. summation of pressure distributions, finite element properties, local averaging); ordinary differential equations (e.g. forced vibrations, beam bending). All course participants will receive source code consisting of a suite of numerical methods programs. 3 hours lecture; 3 semester hours. Prerequisite: CSCI200 or CSCI260 or CSCI261 or MATH307, MATH225.

CEEN406. FINITE ELEMENT METHODS FOR ENGINEERS. 3.0 Semester Hrs.

A course combining finite element theory with practical programming experience in which the multidisciplinary nature of the finite element method as a numerical technique for solving differential equations is emphasized. Topics covered include simple structural elements, beams on elastic foundations, solid elasticity, steady state analysis and transient analysis. Some of the applications will lie in the general area of geomechanics, reflecting the research interests of the instructor. Prerequisite: CEEN311 or MEGN212, MATH225.

CEEN410. ADVANCED SOIL MECHANICS. 3.0 Semester Hrs.

Advanced soil mechanics theories and concepts as applied to analysis and design in geotechnical engineering. Topics covered will include seepage, consolidation, shear strength and probabilistic methods. The course will have an emphasis on numerical solution techniques to geotechnical problems by finite elements and finite differences. 3 hour lectures; 3 semester hours. Fall even years. Prerequisite: CEEN312.

CEEN411. UNSATURATED SOIL MECHANICS. 3.0 Semester Hrs.

Equivalent with CEEN512,

Systematic introduction of soil mechanics under partially saturated conditions. Topics include principles of seepage under variably saturated conditions, principle of the effective stress, shear strength theory, and hydraulic and mechanical properties. When this course is cross-listed and concurrent with CEEN511, students that enroll in CEEN511 will complete additional and/or more complex assignments. Prerequisite: CEEN312.

CEEN415. FOUNDATION ENGINEERING. 3.0 Semester Hrs.

Techniques of subsoil investigation, types of foundations and foundation problems, selection of basis for design of foundation types. Open-ended problem solving and decision making. Prerequisite: CEEN312. 3 hours lecture; 3 semester hours.

CEEN419. RISK ASSESSMENT IN GEOTECHNICAL ENGINEERING. 3.0 Semester Hrs.

Soil and rock are among the most variable of all engineering materials, and as such are highly amenable to a probabilistic treatment. Assessment of the probability of failure or inadequate performance is rapidly gaining ground on the traditional factor of safety approach as a more rational approach to design decision making and risk management. Probabilistic concepts are also closely related to system reliability and Load and Resistance Factor Design (LRFD). When probability is combined with consequences of failure, this leads to the concept of risk. This course is about the theory and application of various tools enabling risk assessment in engineering with an emphasis on geotechnical applications.

Course Learning Outcomes

- Understand basic principles of probability theory and apply them to the geotechnical engineering applications.
- Understand the consequences of design failure and risk in geotechnical engineering
- Have the ability to compute probability in geotechnical engineering using hand and computational tools
- Successfully complete homework assignments and exam questions

CEEN421. HIGHWAY AND TRAFFIC ENGINEERING. 3.0 Semester Hrs.

(I) The emphasis of this class is on the multi-disciplinary nature of highway and traffic engineering and its application to the planning and design of transportation facilities. In the course of the class the students will examine design problems that will involve: geometric design, surveying, traffic operations, hydrology, hydraulics, elements of bridge design, statistics, highway safety, transportation planning, engineering ethics, soil mechanics, pavement design, economics, environmental science. 3 credit hours.

CEEN423. SURVEYING FOR ENGINEERS AND INFRASTRUCTURE DESIGN PRACTICES. 3.0 Semester Hrs.

Applications of civil engineering skills using the engineer's level, total station, GPS receiver, and commercial software for field data collection, design, and layout of civil infrastructure including survey control, roadways, intersections, and utilities such as water and sewer. The course includes basic road design, horizontal design, vertical design, centerline layout, slope/cross section staking, earthwork volume calculations, engineering astronomy, and preparation of plan/profile drawings. Some discussion of concepts and mathematics of applying GPS data to engineering projects and the principles of map projections (Mercator, Lambert, UTM, State Plane, etc.) and coordinate systems such as (North American Datum) NAD '27, NAD '83, and other reference networks is included. Prerequisite: CEEN331. 2 hours lecture; 8-9 field work days; 3 semester hours.

CEEN425. CEMENTITIOUS MATERIALS FOR CONSTRUCTION. 3.0 Semester Hrs.
(II) Cementitious materials, as the most commonly used construction materials, are the main focus of this course and variety of cementitious materials including Portland and non-Portland cements, supplementary cementitious materials, concrete and sprayed concrete (shotcrete), and grouts with their needed additional constituents are covered in this course. This course provides a comprehensive treatment of engineering principles and considerations for proper design, production, placement and maintenance of high quality cementitious materials for infrastructure. In addition, cementitious materials and techniques used for ground improvement purposes are covered in this course. Spring odd years. Prerequisite: CEEN 311.
Course Learning Outcomes

- 1. Describe the main properties of concrete constituents and their influence on the behavior • Describe the cement composition, phases, types, and the hydration process • List the different types of cements and their proper applications • Select the right types of admixtures to be used in different applications and situations • Describe the effects of supplementary cementitious materials on concrete properties
- 2. Design and Test Cementitious Construction materials to meet specifications • Design conventional and high performance Portland cement concrete mixtures with supplementary cementitious materials to meet specifications • Design concrete mix for spraying applications to meet the requirements for ground support needs • Identify the appropriate testing method for evaluation of concrete properties
- 3. Propose ground improvement solutions for different ground conditions using Cementitious Materials • Describe the different ground improvement techniques and explain the differences among current techniques • Identify the appropriate type of ground improvement and specify the requirements for the materials needed
- 4. Apply the concepts learned in the class in understanding the nature, types and applications of cementitious materials by • Selecting a topic of interest related to Cementitious Materials • Conducting research in groups • Presenting the work in written and oral presentation formats

CEEN426. DURABILITY OF CONCRETE. 3.0 Semester Hrs.
(II) This course will provide an in-depth overview of concrete properties relevant to deterioration, including transport, mechanical, physical, and chemical properties. After this course, students should be able to identify, quantify, and mitigate against various deterioration mechanisms, such as freezing and thawing, sulfate attack, alkali-aggregate reactions, acid attack, and corrosion of steel rebar. This course will also illustrate how to test materials for durability (hands-on activities included) and ways in which construction methods may affect durability. Students will learn the strengths and limitations of the worlds most ubiquitous building material.
Course Learning Outcomes

- 1. Explain how the microstructure of concrete develops.
- 2. Explain how the microstructure of concrete affects engineering properties.
- 3. Identify different deterioration mechanisms that affect concrete and explain how they impact concrete durability.
- 4. Explain the principles behind various durability tests.
- 5. Conduct durability tests and assess the performance.

CEEN430. ADVANCED STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Introduction to advanced structural analysis concepts. Nonprismatic structures. Arches, Suspension and cable-stayed bridges. Structural optimization. Computer Methods. Structures with nonlinear materials. Internal force redistribution for statically indeterminate structures. Graduate credit requires additional homework and projects. 3 hour lectures; 3 semester hours. Prerequisite: CEEN314.

CEEN433. MATRIX STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with CEEN533,
Focused study on computer oriented methods for solving determinate and indeterminate structures such as trusses and frames. Classical stiffness based analysis method will be introduced with hands-on practice to develop customized matrix analysis program using Matlab. Commercial structural analysis programs will also be introduced during the class and practiced through class projects. When this course is cross-listed and concurrent with CEEN533, students that enroll in CEEN533 will complete additional and/or more complex assignments. 3 lecture hours, 3 semester hours. Prerequisite: CEEN314.

CEEN442. DESIGN OF WOOD STRUCTURES. 3.0 Semester Hrs.
(II) The course develops the theory and design methods required for the use of wood as a structural material. The design of walls, beams, columns, beam-columns, shear walls, and structural systems are covered with consideration of gravity, wind, snow, and seismic loads. Prerequisite: CEEN311.

CEEN443. DESIGN OF STEEL STRUCTURES. 3.0 Semester Hrs.
To learn application and use the American Institute of Steel Construction (AISC) Steel Construction Manual. Course develops an understanding of the underlying theory for the design specifications. Students learn basic steel structural member design principles to select the shape and size of a structural member. The design and analysis of tension members, compression members, flexural members, and members under combined loading is included, in addition to basic bolted and welded connection design. 3 hours lecture; 3 semester hours. Prerequisite: CEEN314.

CEEN445. DESIGN OF REINFORCED CONCRETE STRUCTURES. 3.0 Semester Hrs.
This course provides an introduction to the materials and principles involved in the design of reinforced concrete. It will allow students to develop an understanding of the fundamental behavior of reinforced concrete under compressive, tensile, bending, and shear loadings, and gain a working knowledge of strength design theory and its application to the design of reinforced concrete beams, columns, slabs, and footings. Prerequisite: CEEN314. 3 hours lecture; 3 semester hours.

CEEN448. STRUCTURAL LOADS. 3.0 Semester Hrs.
Students will be introduced to the load types and load combinations required to design structures in compliance with building code requirements. Students will learn the theory and methods to determine the magnitude and application of loads associated with structure self-weight and occupancy. Students will be introduced to the physics underlying the requirements for environmental loads and to the accepted methods used to calculate environmental loads due to wind, snow, rain, floods, and avalanches. Students will become familiar with the common

approaches used to deal with tsunami loads and blast loads. Students will learn the importance of and to recognize the load paths required to transmit applied loads from the structure to the foundation. Course offered every third semester. Prerequisite: CEEN314.

Course Learning Outcomes

- Students are expected to attend class, ask questions, utilize office hours when needed, and come to class prepared.
- Students are expected to display academic integrity (see Academic Integrity Section).
- Students will be able to determine to applicable loads to be used to design a structure, be able to calculate their magnitudes and directions, and specify load path.

CEEN449. INTRODUCTION TO THE SEISMIC DESIGN OF STRUCTURES. 3.0 Semester Hrs.

This course provides students with an introduction to seismic design as it relates to structures. Students will become familiar with the sources of seismic disturbances, the physics of seismic energy transmission, and the relationship between ground disturbance and the resulting forces experienced by structures. The theory and basis for existing building code provisions relating to seismic design of structures will be introduced. Building code requirements and design methodologies will be examined and applied. Advanced performance based seismic design method will also be introduced. Prerequisite: CEEN443, or CEEN445, or CEEN442 Co-requisite: N/A.

Course Learning Outcomes

- Gain fundamental understanding on earthquake hazard and how it is characterized for structural design.
- Understand typical lateral load path for building structures.
- Gain fundamental understanding of structural dynamics related to earthquake engineering.
- Get familiar with Seismic Design sections in ASCE7, and be able to use ASCE7 to conduct simple seismic design using equivalent lateral force procedure.
- Understand the concept of performance based seismic design method.

CEEN460. MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs.

(I) Essentially, this course will be an introduction to the field of environmental microbiology. Although not titled as such, we will focus on all aspects of environmental microbiology including those of engineered systems. We will be particularly considering things that pertain to life in all of its forms. Expect to engage in diverse conversations pertaining to life in any of its habitats. The class has THREE ESSENTIAL ELEMENTS. The first is the lectures and the material that I, or any of the guest speakers happen to cover. The second is the material that has been assigned in the textbook. Please read the assigned textbook sections thoroughly before coming to class. Also, at times, I will be assigning current papers to read, please read them as assigned. The third is YOUR PARTICIPATION in discussions. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Have a thorough understanding of the microbial world, as of the Fall of 2018.
- Have a new understanding of what life means.
- Have a new understanding of the Earth.
- Have a new understanding of your body.
- Have a new understanding of the rock record and a new perspective on what it means to be a civil / environmental engineer going into the future.

CEEN461. FUNDAMENTALS OF ECOLOGY. 3.0 Semester Hrs.

Biological and ecological principles discussed and industrial examples of their use given. Analysis of ecosystem processes, such as erosion, succession, and how these processes relate to engineering activities, including engineering design and plant operation. Criteria and performance standards analyzed for facility siting, pollution control, and mitigation of impacts. North American ecosystems analyzed. Concepts of forestry, range, and wildlife management integrated as they apply to all of the above. Three to four weekend trips will be arranged during the semester. Semester offering based on faculty availability.

CEEN470. WATER AND WASTEWATER TREATMENT PROCESSES. 3.0 Semester Hrs.

Equivalent with BELS453,EGGN453,ESGN453,

The goal of this course is to familiarize students with the unit operations and processes involved in water and wastewater treatment. This course will focus on the physical, chemical, and biological processes for water and wastewater treatment and reclamation. Treatment objectives, process theory, and practice are considered in detail. Prerequisite: CEEN301.

CEEN472. ONSITE WATER RECLAMATION AND REUSE. 3.0 Semester Hrs.

Appropriate solutions to water and sanitation in the U.S. and globally need to be effective in protecting public health and preserving water quality while also being acceptable, affordable and sustainable. Onsite and decentralized systems have the potential to achieve these goals in rural areas, peri-urban developments, and urban centers in small and large cities. Moreover they can improve water use efficiency, conserve energy and enable distributed energy generation, promote green spaces, restore surface waters and aquifers, and stimulate new green companies and jobs. A growing array of approaches, devices and technologies have evolved that include point-of-use water purification, waste source separation, conventional and advanced treatment units, localized natural treatment systems, and varied resource recovery and recycling options. This course will focus on the engineering selection, design, and implementation of onsite and decentralized systems for water reclamation and reuse. Topics to be covered include process analysis and system planning, water and waste stream attributes, water and resource conservation, confined unit and natural system treatment technologies, effluent collection and clustering, recycling and reuse options, and system management. Prerequisite: CEEN301. 3 hours lecture; 3 semester hours.

CEEN473. HYDRAULIC PROBLEMS. 3.0 Semester Hrs.

Review of fundamentals, forces on submerged surfaces, buoyancy and flotation, gravity dams, weirs, steady flow in open channels, backwater curves, hydraulic machinery, elementary hydrodynamics, hydraulic structures. Prerequisite: CEEN310 or CBEN307.

CEEN475. HAZARDOUS SITE REMEDIATION ENGINEERING. 3.0 Semester Hrs.

This course describes the engineering principles and practices associated with the characterization and remediation of contaminated sites. Methods for site characterization and risk assessment will be highlighted while the emphasis will be on remedial action screening processes and technology principles and conceptual design. Common isolation and containment and in-situ and ex-situ treatment technology will be covered. Computerized decision-support tools will be used and case studies will be presented. Prerequisite: CHGN121.

CEEN478. WATER TREATMENT DESIGN AND ANALYSIS. 3.0 Semester Hrs.

The learning objectives of this class are to build off of the information and theories presented in CEEN 470 and apply them to the design of water and wastewater treatment systems. Students will be presented with project-based assignments and, with the help of the instructors and associated lectures, will use fundamentals and commercial software to develop preliminary designs of water and wastewater systems. Students will gain experience in conventional and advanced treatment system design, software utilized by environmental consulting companies, and professional communication through the completion of this class. Course lectures will include fundamentals of design, guest lectures from practitioners, and tours of local treatment plants. Regional water and wastewater treatment employers (e.g., consultants, municipalities, industry, regulators) are actively searching for students with applied experience and this class will help promote the advancement of employment in the water and wastewater treatment field. Prerequisite: CEEN470.

Course Learning Outcomes

- Use fundamentals and commercial software to design and analyze water treatment systems.
- Integrate design aspects for development of integrated water systems to treat variable water resources.
- Summarize design components into drawings and diagrams.
- Communicate solutions and designs to practitioners through technical reports and presentations.

CEEN479. AIR POLLUTION. 3.0 Semester Hrs.

This course familiarizes students with the basic physics, chemistry and biology of major air pollutants, related health impacts, and engineered approaches used to mitigate the effects of common air pollutants. This course is also designed to provide a solid foundation in air pollution topic areas found on the FEE or PE exam. Critical US air pollution legislation is discussed. The sources of particulate and gaseous pollutants from both stationary and mobile sources, associated key chemical reactions, and approaches for control are considered. Indoor air pollution and the Gaussian dispersion model for air pollutants are discussed. Prerequisite: CEEN302. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Characterize and compare the various types of air pollutants, their sources, fate, and health and environmental risks and impacts.
- Summarize current air quality standards and legislation.
- Identify, characterize, and assess different methods of pollution prevention and source control devices for particulate matter and other air pollutants.
- Predict downwind concentrations of pollutants under varying conditions using air pollution modeling.

CEEN480. CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT. 3.0 Semester Hrs.

Equivalent with ESGN440,

This course describes the environmental behavior of inorganic and organic chemicals in multimedia environments, including water, air, sediment and biota. Sources and characteristics of contaminants in the environment are discussed as broad categories, with some specific examples from various industries. Attention is focused on the persistence, reactivity, and partitioning behavior of contaminants in environmental media. Both steady and unsteady state multimedia environmental models are developed and applied to contaminated sites. The principles of contaminant transport in surface water, groundwater and air are also introduced. The course provides students with the conceptual basis and mathematical tools for predicting the behavior of contaminants in the environment. Prerequisite: CEEN301.

CEEN482. HYDROLOGY AND WATER RESOURCES LABORATORY. 3.0 Semester Hrs.

This course introduces students to the collection, compilation, synthesis and interpretation of data for quantification of the components of the hydrologic cycle, including precipitation, evaporation, infiltration, and runoff. Students will use hydrologic variables and parameters to evaluate watershed processes and behavior. Students will also survey and apply measurement techniques necessary for watershed studies. Advanced topics include development, construction, and application of analytical models for selected problems in hydrology and water resources. Prerequisite: CEEN381. 2 hours lecture; 3 hours lab; 3 semester hours.

CEEN491. EROSION CONTROL AND LAND RESTORATION. 3.0 Semester Hrs.

People have been the main cause of soil erosion for over 1,000 years. Studies suggest that human activities can cause about ten times more erosion than all natural processes together. It is well known that the rates of soil erosion surpass those of soil formation. Worldwide, millions of acres of productive land are lost every year because of inappropriate land management practices. The course is oriented to graduate and undergraduate students from any field in which the relationship among soil, water, and plant is altered, with the purpose of applying the right technique to bring back the productivity of land, in a sustainable way. The student will learn about erosion processes and how to stop them, and by the end of the course the student should be able to: (1) Identify erosive processes affecting certain area; (2) Evaluate the level of soil erosion, its origin and consequences to make further management decisions; and (3) Select and design the most appropriate erosion control/land restoration technique to apply, based on cost-effectiveness, giving emphasis to maximizing environmental benefits (i.e. using plants as a main stabilization system). Prerequisite: CEEN381.

Course Learning Outcomes

- Identify erosive processes affecting certain area.
- Evaluate the level of soil erosion, its origin and consequences, to make further management decisions.
- Select and design the most appropriate erosion control technique to apply, based on cost-effectiveness, giving emphasis to minimizing cost and maximizing environmental benefits (i.e. using plants as a main stabilization system).

CEEN492. ENVIRONMENTAL LAW. 3.0 Semester Hrs.

Equivalent with CEEN592,PEGN530,

Specially designed for the needs of the environmental quality engineer, scientist, planner, manager, government regulator, consultant, or advocate. Highlights include how our legal system works, environmental law fundamentals, all major US EPA/state enforcement programs, the National Environmental Policy Act, air and water pollutant laws, risk assessment and management, and toxic and hazardous substance laws (RCRA, CERCLA, TSCA, LUST, etc). Prerequisites: CEEN301 or CEEN302. 3 hours lecture; 3 semester hours.

CEEN493. SUSTAINABLE ENGINEERING DESIGN. 3.0 Semester Hrs.

This course provides a comprehensive introduction to concepts of sustainability and sustainable development from an engineering point of view. Environmental and health impacts are quantitatively considered in engineering and design analysis through a Life Cycle Assessment (LCA) tool. Social considerations, a key aspect of sustainable engineering

design, are integrated throughout the design analysis. Prerequisite: Senior or graduate standing.
Course Learning Outcomes

- Demonstrate sufficient familiarity with the terminology associated with sustainability and sustainable engineering to speak and write effectively about the topic.
- Compare and contrast traditional engineering design and analysis approaches with those associated with sustainable design, in particular those that go beyond the triple-bottom-line approach to include considerations of social justice and socio-technical integration.
- Apply a working knowledge of a commercially available LCA tool to an engineering design problem.
- Work in teams to effectively (1) write a project report and (2) give a presentation, both of which describe the connection between the concepts of sustainable engineering and their work, the approach they took and their conclusions and recommendations for future work.

CEEN497. PRACTICES AND PRINCIPLES OF ENVIRONMENTAL CONSULTING. 3.0 Semester Hrs.
This course provides an in-depth understanding of the environmental consulting industry with a particular focus on problem solving and project delivery to meet expectations of professional services organizations (environmental consulting firms). Using case studies, real-life consulting assignments, and business scenarios, the course offers exposure to the technical, ethical, and business challenges of winning and executing environmental projects.
Course Learning Outcomes

- 1. Understand the drivers and policies that protect our environmental and water resources.
- 2. Apply knowledge gained in the course from pragmatic problems taken from real scenarios experienced within the consulting industry
- 3. Develop an appreciation for investigations and data interpretation making science-based decisions where possible and determine when decisions may require additional information.
- 4. Know the basic process of project initiation, budgeting, management, and effective delivery in executing environmental projects.
- 5. Work with a team to interpret given data to understand what information is important to advise alternatives, planning, decisions, and design.
- 6. Consider how to tailor designs to meet objectives that protect public health and to meet environment objectives and requirements.
- 7. Use data and engineering judgement to calculate sizing of infrastructure and to develop solutions to solve local environmental problems; research and consider social and economic project considerations and outcomes
- 8. Effectively deliver quality technical products to communicate issues and basis of design; develop communication and presentations skills that effectively share information to an appropriate audience; present technical materials to instructors and peers; provide constructive feedback to peers.

CEEN498. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN499. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Variable credit; 1 to 6 credit hours. Repeatable for credit. Prerequisite: Independent Study form must be completed and submitted to the Registrar.

Professor and Department Head

Junko Munakata Marr

Professor and Associate Department Head

D.V. Griffiths

Professor and James R. Paden Distinguished Chair

Marte Gutierrez

Professor and Grewcock Distinguished Chair

Mike A.Mooney

University Distinguished Professor

Christopher Higgins

Professors

Tzahi Cath

Linda Figueroa

Terri Hogue

Paul C. Johnson

Amy Landis

Ning Lu

John McCray

Jonathan O. Sharp

John R. Spear

Timothy Strathmann

Associate Professors

Eric Anderson

Christopher Bellona

Reza Hedayat

Shiling Pei

Assistant Professors

Yangming Shi

Lori Tunstall

Teaching Professors

Andres Guerra

Kristoph Kinzli

Susan Reynolds

Teaching Associate Professors

Jeffrey Holley

Hongyan Liu

Alexandra Wayllace

Teaching Assistant Professors

Chelsea Panos

Cara Philips

Syd Slouka

Professor of Practice

Karen Gupta

University Emeritus Professor

Bruce Honeyman

Robert L. Siegrist

Emeriti Associate Professor

Ronald R. H. Cohen

Panos Kiousis

Emeritus Teaching Professor

Joseph Crocker

Candace Sulzbach

Chemistry

Degrees Offered

Bachelor of Science in Chemistry (three tracks) certified by American Chemical Society (ACS)

- Chemistry
- Biochemistry
- Environmental Chemistry

Bachelor of Science in Biochemistry (non-ACS)

Program Description

Chemistry is the field of science associated with atoms and molecules, hence nanoscience and beyond. Overall, chemists focus their efforts to understand the behavior and properties of matter, the reactions and transformations that dictate chemical processes, and the creation of new substances. Chemistry is often considered the central science linking the physical sciences with engineering, medicine, and life sciences. The subject of chemistry is typically organized into more focused subdisciplines, including organic chemistry, physical chemistry, inorganic chemistry, biochemistry, analytical chemistry, theoretical/computational chemistry, and materials chemistry. A degree in chemistry examines these topics to promote a fundamental understanding of the world and an application toward technological problems. Professional chemists apply their knowledge in many different areas ranging from environmental and biochemical processes to the development of new materials. They work in academic environments, high-tech start-ups, and research and development laboratories associated with practically every advanced technological field including medicine, energy, biotechnology, computing, and agriculture.

The BS degree program in chemistry is approved by the American Chemical Society (ACS) with a more traditional chemistry track that can be tailored to optimize preparation consistent with a student's individual career goals offered along with specific curricular tracks emphasizing environmental chemistry or biochemistry. These degree tracks are designed to educate professionals for the varied career opportunities this central scientific discipline affords. The curricula are therefore founded in rigorous fundamental science complemented by application of these principles to the materials, energy, minerals, biochemical and/or environmental fields. It is strongly encouraged that those aspiring to enter PhD programs in chemistry or biochemistry are strongly advised to include undergraduate research among their elective hours. Others interested in industrial chemistry choose area of special interest elective courses, in both chemistry and other departments. A number of students complete a dual degree in chemistry and chemical engineering as an excellent preparation for industrial careers.

There is a separate BS degree in Biochemistry which is also offered. The BS degree program in biochemistry is designed to educate professionals for the varied career opportunities this scientific discipline affords, e.g. medicine, veterinary etc. Biochemistry is the field of science concerned with the chemical and physicochemical processes that occur within living organisms. It focuses on molecular genetics, protein science, and metabolism. Almost all areas of the life sciences are being uncovered and developed by biochemical methodology and research. Biochemistry focuses on understanding how biological molecules give rise to the processes that occur within living cells and between cells, which in turn relates greatly to the study and understanding of tissues, organs, organism and microorganism structure and function.

A degree in biochemistry examines these topics to promote a fundamental understanding of the fusion of chemistry and biology and an application toward technological problems. Professional biochemists apply their knowledge in many different areas ranging from environmental processes to the development of new biomaterials, to drug development and even novel renewable bioenergy systems. They work in academic environments, high-tech startups, and research and development laboratories associated with practically every advanced technological field including medicine, energy, biotechnology, computing, and agriculture.

The instructional and research laboratories located in Coolbaugh Hall are state-of-the-art facilities with modern instrumentation for synthesis and characterization of molecules and materials. Instrumentation includes gas chromatographs (GC), high-performance liquid chromatographs (HPLC), inductively coupled-plasma-atomic emission spectrometers (ICP-AES), field-flow fractionation (FFF) equipment, mass spectrometry equipment (MS, GC/MS, GC/MS/MS, PY/MS, PY/GC/MS, SFC/MS, MALDI-TOF), 400 MHz and 500 MHz nuclear magnetic resonance spectrometers (NMR), infrared spectrometers (FTIR), ultraviolet-visible (UV) spectrometers, thermogravimetric analyzers (TGA), differential scanning calorimeters (DSC), and others including equipment for microscopy, light scattering, and elemental analysis. In addition, the campus provides access to the Mines 2,144 core 23 teraflop supercomputer for computational research.

Program Educational Objectives (Bachelor of Science in Chemistry)

In addition to contributing toward achieving the educational objectives described in the Mines Graduate Profile and the ABET accreditation criteria, the BS curricula in chemistry are designed to:

- Impart mastery of chemistry fundamentals.
- Develop ability to apply chemistry fundamentals in solving open-ended problems.
- Impart knowledge of and ability to use modern tools of chemical analysis and synthesis.
- Develop ability to locate and use pertinent information from the chemical literature.
- Develop ability to interpret and use experimental data for chemical systems.
- Develop ability to effectively communicate in both written and oral formats.
- Prepare students for entry to and success in professional careers.
- Prepare students for entry to and success in graduate programs.
- Prepare students for responsible contribution to society.

Curriculum

The BS chemistry curricula, in addition to the strong basis provided by the common core, contain three components: chemistry fundamentals, laboratory and communication skills, and applications courses.

Chemistry fundamentals

- Analytical chemistry – sampling, method selection, statistical data analysis, error sources, theory of operation of analytical instruments (atomic and molecular spectroscopy, mass spectrometry, nuclear magnetic resonance spectroscopy, chromatography and other separation methods, electroanalytical methods, and thermal methods), calibration, standardization, stoichiometry of analysis, equilibrium, and kinetic principles in analysis.
- Inorganic chemistry – atomic structure and periodicity, crystal lattice structure, molecular geometry and bonding (VSEPR, Lewis structures, VB and MO theory, bond energies, and lengths), metals structure and properties, acid-base theories, main-group element chemistry, coordination chemistry, term symbols, ligand field theory, spectra and magnetism of complexes, organometallic chemistry, and nanomaterials chemistry and design.
- Organic chemistry – bonding and structure, structure- physical property relationships, reactivity-structure relationships, reaction mechanisms (nucleophilic and electrophilic substitution, addition, elimination, radical reactions, rearrangements, redox reactions, photochemical reactions, and metal-mediated reactions), chemical kinetics, catalysis, major classes of compounds and their reactions, and design of synthetic pathways.
- Physical chemistry – thermodynamics (energy, enthalpy, entropy, equilibrium constants, free energy, chemical potential, non-ideal systems, standard states, activity, phase rule, phase equilibria, phase diagrams), electrochemistry, kinetic theory (Maxwell-Boltzmann distribution, collision frequency, effusion, heat capacity, equipartition of energy), kinetics (microscopic reversibility, relaxation processes, mechanisms and rate laws, collision and absolute rate theories), quantum mechanics (Schroedinger equations, operators and matrix elements, particle-in-a-box, simple harmonic oscillator, rigid rotor, angular momentum, hydrogen atom, hydrogen wave functions, spin, Pauli principle, LCAO method, MO theory, bonding), spectroscopy (dipole selection rules, rotational spectra, term symbols, atomic and molecular electronic spectra, magnetic spectroscopy, Raman spectroscopy, multiphoton selection rules, lasers), statistical thermodynamics (ensembles, partition functions, Einstein crystals, Debye crystals), group theory, surface chemistry, X-ray crystallography, electron diffraction, dielectric constants, dipole moments, and elements of computational chemistry.

Laboratory and communication skills

- Analytical methods – gravimetry, titrimetry, sample dissolution, quantitative spectroscopy, GC, HPLC, GC/MS, potentiometry, NMR, AA, ICP-AES
- Synthesis techniques – batch reactor assembly, inert-atmosphere manipulations, vacuum line methods, high-temperature methods, high-pressure methods, distillation, recrystallization, extraction, sublimation, chromatographic purification, product identification
- Physical measurements – refractometry, viscometry, colligative properties, FTIR, NMR
- Information retrieval – Chemical Abstracts online searching, CA registry numbers, Beilstein, Gmelin, handbooks, organic syntheses, organic reactions, inorganic syntheses, primary sources, ACS Style Guide
- Reporting – lab notebook, experiment and research reports, technical oral reports
- Communication – scientific reviews, seminar presentations, publication of research results

Applications

- Elective courses – application of chemistry fundamentals in chemistry elective courses or courses in another discipline e.g., chemical engineering, environmental science, materials science.
- Internship – summer or semester experience in an industrial or governmental organization working on real-world problems.
- Undergraduate research – open-ended problem solving in the context of a research project.

Degree Requirements for Bachelor of Science in Chemistry

Degree Requirements (Chemistry Track)

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
EDNS151	CORNERSTONE - DESIGN I			3.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
S&W	SUCCESS AND WELLNESS			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0

		lec	lab	sem.hrs
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
PHGN100	PHYSICS I - MECHANICS			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I			3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY			1.0
				15.0

Spring		lec	lab	sem.hrs
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
HASS200	GLOBAL STUDIES			3.0
CHGN222	ORGANIC CHEMISTRY II			3.0
CHGN224	ORGANIC CHEMISTRY II LABORATORY			1.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
CHGN335	INSTRUMENTAL ANALYSIS			3.0
				16.0

Junior

Fall		lec	lab	sem.hrs
CHGN336	ANALYTICAL CHEMISTRY			3.0
CHGN337	ANALYTICAL CHEMISTRY LABORATORY			1.0
CHGN341	INORGANIC CHEMISTRY I			3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I			4.0
CHGN395	INTRODUCTION TO UNDERGRADUATE RESEARCH			1.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective			3.0
				18.0

Spring		lec	lab	sem.hrs
CHGN353	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II			4.0
CHGN323	QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY			2.0
CHGN428	BIOCHEMISTRY			3.0
TECH ELECT	Technical Elective*			3.0
TECH ELECT	Technical Elective*			3.0
				15.0

Summer		lec	lab	sem.hrs
CHGN490	CHEMISTRY FIELD SESSION		18.0	6.0
				6.0

Senior

Fall		lec	lab	sem.hrs
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
CHGN ELECT	Chemistry Elective**			3.0
TECH ELECT	Technical Elective*			3.0
TECH ELECT	Technical Elective*			3.0
FREE	Free Elective			3.0
				15.0

Spring		lec	lab	sem.hrs
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
CHGN401	INORGANIC CHEMISTRY II			3.0
CHGN ELECT	Chemistry Elective**			2.0
TECH ELECT	Technical Elective*			3.0
FREE	Free Elective			3.0
				14.0

Total Semester Hrs: 131.0

* Technical electives are courses in any technical field. HASS, PAGN, Military Science, ROTC, McBride and the business courses of EBGN are ***not*** accepted technical electives. Examples of possible electives that will be recommended to students are:

CEEN301	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER	3.0
CHGN411	APPLIED RADIOCHEMISTRY	3.0
CHGN430	INTRODUCTION TO POLYMER SCIENCE	3.0
CHGN462	MICROBIOLOGY	3.0
EBGN305	FINANCIAL ACCOUNTING	3.0
EBGN306	MANAGERIAL ACCOUNTING	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
MATH201	INTRODUCTION TO STATISTICS	3.0
MATH332	LINEAR ALGEBRA	3.0
MNGN210	INTRODUCTORY MINING	3.0

MTGN211	STRUCTURE OF MATERIALS	3.0
PEGN201	PETROLEUM ENGINEERING FUNDAMENTALS	3.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0

** Chemistry electives are non-required courses taught within the Chemistry Department. In addition, graduate-level Chemistry and Geochemistry courses taught within the department are acceptable.

CHGN495 SENIOR UNDERGRADUATE RESEARCH is taught as a possible chemistry elective. Those aspiring to enter PhD programs in Chemistry or related fields are strongly advised to include undergraduate research in their curricula. The objective of CHGN495 is that students successfully perform an open-ended research project under the direction of a CSM faculty member. Students must demonstrate through the preparation of a proposal, prepared in consultation with the potential faculty research advisor and the CHGN495 instructor, that they qualify for enrollment in CHGN495.

Degree Requirements (Environmental Chemistry Track)

Freshman

Fall		lec	lab	sem.hrs
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS or CBEN 110			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
				16.0

Spring		lec	lab	sem.hrs
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I			3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY			1.0
HASS200	GLOBAL STUDIES			3.0
				18.0

Spring		lec	lab	sem.hrs
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
CHGN222	ORGANIC CHEMISTRY II			3.0
CHGN224	ORGANIC CHEMISTRY II LABORATORY			1.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
CHGN335	INSTRUMENTAL ANALYSIS			3.0
				16.0

Junior

Fall		lec	lab	sem.hrs
CHGN336	ANALYTICAL CHEMISTRY			3.0
CHGN337	ANALYTICAL CHEMISTRY LABORATORY			1.0
CHGN341	INORGANIC CHEMISTRY I			3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I			4.0
CHGN395	INTRODUCTION TO UNDERGRADUATE RESEARCH			1.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
CHEV ELECT	Environmental Elective**			3.0
				18.0

Spring		lec	lab	sem.hrs
CHGN353	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II			4.0
CHGN323	QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY			2.0
CHGN428	BIOCHEMISTRY			3.0
CHEV ELECT	Environmental Elective**			3.0
TECH ELECT	Technical Elective*			3.0
				15.0

Summer		lec	lab	sem.hrs
CHGN490	CHEMISTRY FIELD SESSION		18.0	6.0
				6.0

Senior				
Fall		**lec**	**lab**	**sem.hrs**
CHEV ELECT	Environmental Elective**			3.0
CHEV ELECT	Environmental Elective**			3.0
CHGN ELECT	Chemistry Elective**			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
CHGN410	SURFACE CHEMISTRY			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY			3.0
CHGN ELECT	Chemistry Elective**			2.0
S&W	SUCCESS AND WELLNESS			1.0
FREE	Free Elective	3.0		3.0
				15.0
Total Semester Hrs: 135.0				

* Technical electives are courses in any technical field. HASS, PAGN, Military Science and ROTC, McBride and the business courses of EBGN are ***not*** accepted technical electives.

** Chemistry electives are non-required courses taught within the Chemistry department. In addition, graduate-level Chemistry and Geochemistry courses taught within the department are acceptable.

Environmental electives are courses that are directly or indirectly related to Environmental Chemistry. Examples include environmental CEEN courses and CHGN462. Students can consult their advisors for further clarification.

CHGN495 SENIOR UNDERGRADUATE RESEARCH is taught as a possible chemistry elective. Those aspiring to enter PhD programs in Chemistry or related fields are strongly advised to include undergraduate research in their curricula. The objective of CHGN495 is that students successfully perform an open-ended research project under the direction of a CSM faculty member. Students must demonstrate through the preparation of a proposal, prepared in consultation with the potential faculty research advisor and the CHGN495 instructor, that they qualify for enrollment in CHGN495.

Degree Requirements (Biochemistry Track)

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0

Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I			3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY			1.0
HASS200	GLOBAL STUDIES			3.0
				18.0
Spring		**lec**	**lab**	**sem.hrs**
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
CHGN222	ORGANIC CHEMISTRY II			3.0
CHGN224	ORGANIC CHEMISTRY II LABORATORY			1.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
CHGN335	INSTRUMENTAL ANALYSIS			3.0
				16.0

Junior				
Fall		**lec**	**lab**	**sem.hrs**
TECH ELECT	Technical Elective*			4.0
CHGN336	ANALYTICAL CHEMISTRY			3.0

		lec	lab	sem.hrs
CHGN337	ANALYTICAL CHEMISTRY LABORATORY			1.0
CHGN341	INORGANIC CHEMISTRY I			3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I			4.0
CHGN395	INTRODUCTION TO UNDERGRADUATE RESEARCH			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CHGN353	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II			4.0
CHGN323	QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY			2.0
CHGN428	BIOCHEMISTRY			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
CBEN120	FUNDAMENTALS OF BIOLOGY II			4.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
CHGN490	CHEMISTRY FIELD SESSION		18.0	6.0
				6.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
CHGN429	BIOCHEMISTRY II			3.0
CHGN ELECT	Chemistry Elective**			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
TECH ELECT	Technical Elective*			3.0
FREE	Free Elective			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
CHGN401	INORGANIC CHEMISTRY II			3.0
CHGN ELECT	Chemistry Elective**			2.0
S&W	SUCCESS AND WELLNESS			1.0
FREE	Free Elective	3.0		3.0
FREE	Free Elective	3.0		3.0
				15.0

Total Semester Hrs: 134.0

* Technical electives are courses in any technical field. HASS, PAGN, Military Science and ROTC, McBride and the business courses of EBGN are ***not*** accepted technical electives. * Possible technical electives that will be recommended to students are:

CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0
CHGN462	MICROBIOLOGY	3.0
CBEN304	ANATOMY AND PHYSIOLOGY	3.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN321	INTRO TO GENETICS	4.0

** Chemistry electives are non-required courses taught within the Chemistry department. In addition, graduate-level Chemistry and Geochemistry courses taught within the department are acceptable.

CHGN495 SENIOR UNDERGRADUATE RESEARCH is taught as a possible chemistry elective. Those aspiring to enter Ph.D. programs in Chemistry or related fields are strongly advised to include undergraduate research in their curricula. The objective of CHGN495 is that students successfully perform an open-ended research project under the direction of a CSM faculty member. Students must demonstrate through the preparation of a proposal, prepared in consultation with the potential faculty research advisor and the CHGN495 instructor, that they qualify for enrollment in CHGN495.

Degree Requirements for Bachelor of Science in Biochemistry

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I			3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY			1.0

		lec	lab	sem.hrs
HASS200	GLOBAL STUDIES			3.0
				18.0

Spring		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
CHGN335	INSTRUMENTAL ANALYSIS			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
CHGN222	ORGANIC CHEMISTRY II			3.0
CHGN224	ORGANIC CHEMISTRY II LABORATORY			1.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
				16.0

Junior

Fall		lec	lab	sem.hrs
CHGN341	INORGANIC CHEMISTRY I			3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I			4.0
CHGN395	INTRODUCTION TO UNDERGRADUATE RESEARCH			1.0
CHGN336	ANALYTICAL CHEMISTRY			3.0
CHGN337	ANALYTICAL CHEMISTRY LABORATORY			1.0
TECH ELECT	Technical Elective			4.0
				16.0

Spring		lec	lab	sem.hrs
CHGN428	BIOCHEMISTRY			3.0
CHGN323	QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY			2.0
CHGN431	INTRODUCTORY BIOCHEMISTRY LABORATORY			2.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective I			3.0
CBEN120	FUNDAMENTALS OF BIOLOGY II			4.0
CHGN ELECT	Chemistry Elective			3.0
				17.0

Summer		lec	lab	sem.hrs
CHGN490	CHEMISTRY FIELD SESSION			6.0
				6.0

Senior

Fall		lec	lab	sem.hrs
CHGN429	BIOCHEMISTRY II			3.0
CHGN ELECT	Chemistry Elective			3.0
TECH ELECT	Technical Elective			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective II			3.0
FREE ELECT	Free Elective			3.0
				15.0

Spring		lec	lab	sem.hrs
CHGN ELECT	Chemistry Elective			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective III			3.0
FREE ELECT	Free Elective			3.0
FREE ELECT	Free Elective			3.0
S&W	SUCCESS AND WELLNESS			1.0
				13.0

Total Semester Hrs: 133.0

CHGN Electives:

CHGN311	INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY	3.0
CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0
CHGN409	BIOLOGICAL INORGANIC CHEMISTRY	3.0
CHGN441	THE CHEMISTRY AND BIOCHEMISTRY OF PHARMACEUTICALS	3.0
CHGN445	CHEMICAL BIOLOGY	3.0
CHGN462	MICROBIOLOGY	3.0
CHGN495	UNDERGRADUATE RESEARCH	1-5

Tech Electives:

CBEN304	ANATOMY AND PHYSIOLOGY	3.0
CBEN305	ANATOMY AND PHYSIOLOGY LAB	1.0
CBEN311	INTRODUCTION TO NEUROSCIENCE	3.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN321	INTRO TO GENETICS	4.0
CBEN322	BIOLOGICAL PSYCHOLOGY	3.0
CBEN411	NEUROSCIENCE, MEMORY, AND LEARNING	3.0
CBEN431	IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS	3.0

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- CHGC100 through CHGC599 inclusive
- CHGN100 through CHGN599 inclusive

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Chemistry Minor and ASI Programs

No specific course sequences are suggested for students wishing to include chemistry minors or areas of special interest in their programs. Rather, those students should consult with the Chemistry department head (or designated faculty member) to design appropriate sequences. For the purpose of completing a minor in Chemistry, the Organic Chemistry sequence is exempt from the 100–200-level limit.

ASI programs include Chemistry, Polymer Chemistry, Environmental Chemistry, and Biochemistry. Refer to the main ASI section of the Bulletin for applicable rules for Areas of Special Interest (p. 30).

Courses

CHGN111. INTRODUCTORY CHEMISTRY. 3.0 Semester Hrs.
(S) Introductory college chemistry. Elementary atomic structure and the periodic chart, chemical bonding, chemical reactions and stoichiometry of chemical reactions, chemical equilibrium, thermochemistry, and properties of gases. Must not be used for elective credit. Does not apply toward undergraduate degree or g.p.a. 3 hours lecture and 3 hours lab; 3 semester hours.

CHGN121. PRINCIPLES OF CHEMISTRY I. 4.0 Semester Hrs.
Study of matter and energy based on atomic structure, correlation of properties of elements with position in periodic chart, chemical bonding, geometry of molecules, phase changes, stoichiometry, solution chemistry, gas laws, and thermochemistry. 3 hours lecture, 3 hours lab; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1.

CHGN122. PRINCIPLES OF CHEMISTRY II (SC1). 4.0 Semester Hrs.
Continuation of CHGN121 concentrating on chemical kinetics, gas laws, thermodynamics, electrochemistry and chemical equilibrium (acid- base, solubility, complexation, and redox). Laboratory experiments emphasizing quantitative chemical measurements. 3 hours lecture; 3 hours lab, 4 semester hours. Prerequisite: Grade of C- or better in CHGN121.

CHGN125. MOLECULAR ENGINEERING & MATERIALS CHEMISTRY. 4.0 Semester Hrs.
Studies of the interactions of matter and energy in chemical reactions and physical processes. Building on principles from CHGN121, the course systematically explores the relationships between processes, structures and properties, starting from the atomic and molecular level. It provides a framework to apply knowledge of chemical bonding and material properties to engineering design, with an emphasis on the Engineering Grand Challenges and the discovery of new process-structure-property relationships. There is a strong focus on the underlying principles of kinetics and equilibrium, and their general applicability, strongly rooted in the first and second law of thermodynamics. Examples of these principles come primarily from solid-state systems. Laboratory experiments emphasize conceptual understanding of structure-property relationships through both hands-on and computational analysis, reinforced by quantitative chemical measurements. Prerequisite: Grade of C- or better in CHGN121. 3 hours lecture; 3 hours lab; 4 semester hours.

Course Learning Outcomes

- Knowledge: A student will be able to:
- Comprehension: A student will be able to:
- Application: A student will be able to:
- Analysis: A student will be able to:

CHGN198. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN209. INTRODUCTION TO CHEMICAL THERMODYNAMICS. 3.0 Semester Hrs.
Introduction to the fundamental principles of classical thermodynamics, with particular emphasis on chemical and phase equilibria. Volume-temperature-pressure relationships for solids, liquids, and gases; ideal and non-ideal gases. Introduction to kineticmolecular theory of ideal gases and the Maxwell-Boltzmann distributions. Work, heat, and application of the First Law to closed systems, including chemical reactions. Entropy and the Second and Third Laws; Gibbs Free Energy. Chemical equilibrium and the equilibrium constant; introduction to activities & fugacities. One- and two-component phase diagrams; Gibbs Phase Rule. May not also receive credit for CBEN210 or GEGN330. Prerequisites: CHGN121, CHGN122 or CHGN125, MATH111, MATH112, PHGN100. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- No change

CHGN221. ORGANIC CHEMISTRY I. 3.0 Semester Hrs.
Structure, properties, and reactions of the important classes of organic compounds, introduction to reaction mechanisms. Prerequisites: Grade of C- or better in CHGN122 or CHGN125. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- No change

CHGN222. ORGANIC CHEMISTRY II. 3.0 Semester Hrs.
Continuation of CHGN221. 3 hours lecture; 3 semester hours. Prerequisite: Grade of C- or better in CHGN221.

CHGN223. ORGANIC CHEMISTRY I LABORATORY. 1.0 Semester Hr.
Laboratory exercises including purification techniques, synthesis, and characterization. Experiments are designed to support concepts presented in the CHGN221. Students are introduced to Green Chemistry principles and methods of synthesis and the use of computational software. 3 hours laboratory, 1 semester hour. Prerequisite: CHGN221 or concurrent enrollment.

CHGN224. ORGANIC CHEMISTRY II LABORATORY. 1.0 Semester Hr.
Laboratory exercises using more advanced synthesis techniques. Experiments are designed to support concepts presented in CHGN222.

CHGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN311. INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY. 3.0 Semester Hrs.
The primary objective of this course is to provide all students a suitable background to understand the role nanotechnology will play in future technologies and the underpinning principals involved. 3 hours lecture; 3 semester hours. Prerequisite: CHGN121.
Course Learning Outcomes

- None

CHGN323. QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY. 2.0 Semester Hrs.
Identification, separation and purification of organic compounds including use of modern physical and instrumental methods. 1 hour lecture; 3 hours lab; 2 semester hours. Prerequisite: Grade of C- or better in CHGN222, CHGN224.

CHGN335. INSTRUMENTAL ANALYSIS. 3.0 Semester Hrs.
Principles of AAS, AES, Visible-UV, IR, NMR, XRF, XRD, XPS, electron, and mass spectroscopy; gas and liquid chromatography; data interpretation. Prerequisite: CHGN122 with a grade of C- or better or CHGN125 with a grade of C- or better.

CHGN336. ANALYTICAL CHEMISTRY. 3.0 Semester Hrs.
Theory and techniques of gravimetry, titrimetry (acid-base, complexometric, redox, precipitation), electrochemical analysis, chemical separations; statistical evaluation of data. Prerequisite: CHGN221, CHGN122 with a grade of C- or better or CHGN125 with a grade of C- or better.

CHGN337. ANALYTICAL CHEMISTRY LABORATORY. 1.0 Semester Hr.
Laboratory exercises emphasizing sample preparation and instrumental methods of analysis. Prerequisite: CHGN221 (C- or better), CHGN 223. Co-requisite: CHGN336.

CHGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I, II, S) Supervised, full-time, chemistry-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

CHGN341. INORGANIC CHEMISTRY I. 3.0 Semester Hrs.
The chemistry of the elements and periodic trends in reactivity is discussed. Particular concepts covered include group theory, symmetry, bonding in ionic and metallic crystal, acid-base theories, coordination chemistry, ligand field theory and radioactivity. 3 hours lecture; 3 semester hours. Prerequisite: CHGN222 and CHGN209 or CBEN210.
Course Learning Outcomes

- Students should be able to assess, evaluate or apply periodic trends, group theory, coordination chemistry, molecular orbital theory and crystal field theory.

CHGN351. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I. 4.0 Semester Hrs.
A study of chemical systems from a molecular physical chemistry perspective. Includes an introduction to quantum mechanics, atoms and molecules, spectroscopy, bonding and symmetry, and an introduction to modern computational chemistry. Prereqs: MATH225, PHGN200, CHGN209 with a grade of C- or better or CBEN210.
Course Learning Outcomes

- No change

CHGN353. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II. 4.0 Semester Hrs.
A continuation of CHGN351. Includes statistical thermodynamics, chemical kinetics, chemical reaction mechanisms, electrochemistry, and selected additional topics. 3 hours lecture; 3 hours laboratory; 4 semester hours. Prerequisite: CHGN351.

CHGN395. INTRODUCTION TO UNDERGRADUATE RESEARCH. 1.0 Semester Hr.
(I) (WI) Introduction to Undergraduate Research is designed to introduce students to the research endeavor. Topics include ethics, hypothesis testing, critical evaluation of the scientific literature, scientific writing, bibliographic software, and proposal preparation. Prerequisites: Completion of the chemistry curriculum through the Spring semester of the sophomore year. Credit: 1 semester hour.

CHGN396. UNDERGRADUATE RESEARCH. 1-5 Semester Hr.
(I,II,S) Individual research project for freshman, sophomores or juniors under direction of a member of the departmental faculty. Prerequisites: None. Variable credit; 1 to 5 credit hours. Repeatable for credit. Seniors should take CHGN495 instead of CHGN396.

CHGN398. SPECIAL TOPICS IN CHEMISTRY. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN401. INORGANIC CHEMISTRY II. 3.0 Semester Hrs.
The chemistry of the elements and several applications are related to inorganic chemistry are considered in this course. Particular concepts covered include experimental techniques, chemistry specific to groups of elements, catalysis and industrial processes, inorganic materials and nanotechnology, and other applications of inorganic chemistry. Prerequisite: CHGN341. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Students should be able to apply fundamental considerations of inorganic chemistry to "real world" scenarios.

CHGN403. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGC505,

Processes by which natural and anthropogenic chemicals interact, react and are transformed and redistributed in various environmental compartments. Air, soil and aqueous (fresh and saline surface and groundwaters) environments are covered, along with specialized environments such as waste treatment facilities and the upper atmosphere. Prerequisites: CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- NA

CHGN406. INTRODUCTION TO GEOCHEMISTRY. 3.0 Semester Hrs.
A comprehensive introduction to the basic concepts and principles of geochemistry, coupled with a thorough overview of related principles of thermodynamics and kinetics. Topics covered include: chemical bonding, key chemical reactions, mineral chemistry, soils and nanogeoscience, differentiation of the earth, controls on natural waters, stable and radiogenic isotopes and organic and biogeochemistry. Prerequisite: CHGN122 or CHGN125, GEGN101.
Course Learning Outcomes

- None

CHGN409. BIOLOGICAL INORGANIC CHEMISTRY. 3.0 Semester Hrs.
This course starts with a short introduction to inorganic chemistry and biology. The course then focuses on core bioinorganic chemistry topics, including metalloprotein structure and function; characterization of bioinorganic systems; metal assimilation, metabolism, and homeostasis; and metals in medicine. We also briefly cover special topics, such as metallo-endocrinology, extremophiles, biomineralization, and supramolecular bioinorganic chemistry. We investigate recent advances in the field of bioinorganic chemistry, introduce many leading scientists in the field, and explore scientific literature. Students are assessed through two open-resource, take-home exams (midterm and final) covering course material. Students also explore a topic of their choice through a class presentation and a writing assignment. Students will benefit from having taken at least one of the following courses: organic chemistry, inorganic chemistry, or biochemistry.

CHGN410. SURFACE CHEMISTRY. 3.0 Semester Hrs.
Equivalent with MLGN510,
Introduction to colloid systems, capillarity, surface tension and contact angle, adsorption from solution, micelles and micro - emulsions, the solid/gas interface, surface analytical techniques, van der Waal forces, electrical properties and colloid stability, some specific colloid systems (clays, foams and emulsions). Students enrolled for graduate credit in MLGN510 must complete a special project. Prerequisite: CHGN209 or CBEN210.

CHGN411. APPLIED RADIOCHEMISTRY. 3.0 Semester Hrs.
This course is designed for those who have a budding interest radiochemistry and its applications. A brief overview of radioactivity and general chemistry will be provided in the first three weeks of the course. Follow-on weeks will feature segments focusing on the radiochemistry in the nuclear fuel cycle, radioisotope production, nuclear forensics and the environment. Prerequisite: CHGN122 or CHGN125.

CHGN422. POLYMER CHEMISTRY LABORATORY. 1.0 Semester Hr.
Prerequisites: CHGN221, CHGN223. 3 hours lab; 1 semester hour.

CHGN423. SOLID-STATE CHEMISTRY. 3.0 Semester Hrs.
Dependence of properties of solids on chemical bonding and structure; principles of crystal growth, crystal imperfections, reactions and diffusion in solids, and the theory of conductors and semiconductors Prerequisite: CHGN 121.
Course Learning Outcomes

- 1. Develop foundational understanding of the atomic structure of crystalline solid-state materials, including symmetry, crystal systems, Bravais lattices, space groups, and Miller indices. Connect these concepts to diffraction and scattering
- 2. Connect bonding and electronic structure to functional properties, i.e. electronic transport, light absorption and emission, phonons/lattice dynamics, etc.
- 3. Develop the ability to critically read, synthesize, and discuss the literature corpus surrounding concepts in solid-state materials chemistry.

CHGN428. BIOCHEMISTRY. 3.0 Semester Hrs.
Introductory study of the major molecules of biochemistry: amino acids, proteins, enzymes, nucleic acids, lipids, and saccharides- their structure, chemistry, biological function, and biosynthesis. Stresses bioenergetics and the cell as a biological unit of organization. Discussion of classical genetics, molecular genetics, and protein synthesis. Co-requisite: CHGN222.

CHGN429. BIOCHEMISTRY II. 3.0 Semester Hrs.
A continuation of CHGN428. Topics include: nucleotide synthesis; DNA repair, replication and recombination; transcription, translation and regulation; proteomics; lipid and amino acid synthesis; protein target and degradation; membranes; receptors and signal transduction. Prerequisite: CHGN428.

CHGN430. INTRODUCTION TO POLYMER SCIENCE. 3.0 Semester Hrs.
Equivalent with MLGN530,
An introduction to the chemistry and physics of macromolecules. Topics include the properties and statistics of polymer solutions, measurements of molecular weights, molecular weight distributions, properties of bulk polymers, mechanisms of polymer formation, and properties of thermosets and thermoplastics including elastomers. Pre requisite: CHGN222. 3 hour lecture, 3 semester hours.

CHGN431. INTRODUCTORY BIOCHEMISTRY LABORATORY. 2.0 Semester Hrs.
The link between the structure of a material and its properties is ubiquitous across all fields. Throughout the Biochemistry lab course, we will have the opportunity to explore both protein and nucleic acids through various techniques and analyses that probe the structure-property relationship of biomolecules that subsequently allows us to tap into molecular function. The selection of experiments is intentionally designed to provide exposure to a broad range of modern experimental strategies to enrich and solidify material covered within the CHGN428/429 sequence. Co-requisite: CHGN428.
Course Learning Outcomes

- Students will gain proficiency in basic biochemistry laboratory techniques.
- Students will generate hypotheses and analyze data.

CHGN435. PHYSICAL BIOCHEMISTRY. 3.0 Semester Hrs.
Apply physical chemical principles to understand property-function relationships of biochemical molecules, and investigate biochemical instrumentation and quantitative analyses common to biochemistry. Methods discussed include light/fluorescence microscopy, biomolecular structure determination, i.e., X-ray crystallography, cryo-electron microscopy and NMR, scattering techniques, biomolecular motors, and more. Prerequisite: CHGN 428 + CHGN 209 or equivalent (CBEN 210 or BIOL 301) Co-requisite: N/A.

Course Learning Outcomes

- 1) Demonstrate basic knowledge of thermodynamics and statistical mechanics, and their applications in biochemistry
- 2) Demonstrate basic knowledge of quantum mechanics and its applications in biochemistry
- 3) Demonstrate basic knowledge of common spectroscopic and imaging methods used in biochemistry
- 4) Develop grant-writing skills, particularly in relation to explaining scientific concepts clearly and concisely
- 5) Develop oral presentation skills when disseminating scientific information

CHGN441. THE CHEMISTRY AND BIOCHEMISTRY OF PHARMACEUTICALS. 3.0 Semester Hrs.
This course will examine a broad range of pharmaceuticals, including but not limited to controlled substances, treatments for cardiovascular, respiratory, and infectious diseases, as well as cannabinoids and performance-enhancing substances. The history, pharmacology, and, in some cases, the synthesis of these pharmaceuticals will be covered. Prerequisite: CHGN222, CHGN428.
Course Learning Outcomes

- Students will be able to describe different general mechanisms of action of pharmaceuticals
- Describe different chemical treatments to specific ailments and diseases along with side effects
- Differentiate site and mechanism of action and how agonists and antogonist drugs interact at drug receptor sites
- Explain nomenclature used to name and classify drugs

CHGN445. CHEMICAL BIOLOGY. 3.0 Semester Hrs.
The analysis of biological systems from the perspective of organic/inorganic and physical chemistry, including chemical reactions for the synthetic preparation of biomolecules and the chemistry behind different biotechnological developments and tools. A strong emphasis on the mechanistic basis of biochemical transformations is included. Strategies for directing pharmaceuticals or diagnostics to different subcellular locales will be presented. A survey of key advancements in the field of chemical biology will be drawn from the primary literature. Prerequisite: CHGN 222, CHGN 428.
Course Learning Outcomes

- 1. Understand the molecular-level and atomistic origins of how structure imparts reactivity, based on principles from organic and physical organic chemistry.
- 2. Develop a working knowledge of strategies to direct chemical reagents to different subcellular locales.
- 3. Become familiar with the primary literature describing key advances in the field of chemical biology.
- 4. Be able to use the theories, concepts, and tools of chemical biology to predict how compounds may interact with biological systems.
- 5. Propose novel research to address an outstanding question in the field.

CHGN462. MICROBIOLOGY. 3.0 Semester Hrs.
Equivalent with CHGN562,
(II) This course will cover the basic fundamentals of microbiology, such as structure and function of prokaryotic versus eukaryotic cells; viruses; classification of microorganisms; microbial metabolism, energetics, genetics, growth and diversity, microbial interactions with plants, animals, and other microbes. Special focus will be on pathogenic bacteriology, virology, and parasitology including disease symptoms, transmission, and treatment. Prerequisite: none. 3 hours lecture, 3 semester hours.

CHGN475. COMPUTATIONAL CHEMISTRY. 3.0 Semester Hrs.
This class provides a survey of techniques of computational chemistry, including quantum mechanics (both Hartree-Fock and density functional approaches) and molecular dynamics. Emphasis is given to the integration of these techniques with experimental programs of molecular design and development. Prerequisites: CHGN351, CHGN401. 3 hours lecture; 3 semester hours.

CHGN490. CHEMISTRY FIELD SESSION. 6.0 Semester Hrs.
(WI) Professional-level chemistry experience featuring modules including organic/polymer synthesis and characterization, inorganic nanomaterial investigations, computational chemistry, environmental chemical analysis , biochemistry and technical report writing. 6-week summer session; 6 semester hours. Prerequisite: CHGN323, CHGN341, and CHGN351.

CHGN495. UNDERGRADUATE RESEARCH. 1-5 Semester Hr.
(I, II, S) (WI) Individual research project under direction of a member of the Departmental faculty. Prerequisites: selection of a research topic and advisor, preparation and approval of a research proposal, completion of chemistry curriculum through the junior year. Variable credit; 1 to 5 credit hours. Repeatable for credit.

CHGN497. INTERNSHIP. 1-6 Semester Hr.
(I, II, S) Individual internship experience with an industrial, academic, or governmental host supervised by a Departmental faculty member. Prerequisites: Completion of chemistry curriculum through the junior year. Variable credit; 1 to 6 credit hours.

CHGN498. SPECIAL TOPICS IN CHEMISTRY. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN499. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Professors

Thomas Albrecht-Schönzart, Distinguished Professor

Thomas Gennett, Department Head

Richard C. Holz, Provost

Mark P. Jensen, Grandey University Chair in Nuclear Science & Engineering

Daniel M. Knauss, Associate Dean of Energy and Materials

Matthew C. Posewitz

James F. Ranville

Ryan M. Richards

Alan S. Sellinger

Jenifer C. Shafer

Bettina M. Voelker

David T. Wu

Associate Professors

Svitlana Pylypenko

Brian G. Trewyn

Shubham Vyas

Assistant Professors

Dylan Domaille

Annalise Maughan

C. Michael McGuirk

Christine Morrison

Teaching Professors

Renee L. Falconer, Associate Department Head

Angela Sower

Teaching Assistant Professors

Christian Beren

Amanda Jameer

Kara Metzger

Jonathan Miorelli

Research Professors

Mark E. Eberhart

Kim R. Williams

Research Assistant Professors

Shane Galley

Jessica Jackson

Yuan Yang

Joint Appointees

Matthew Beard

Todd Deutsch

Jesse Hensley

Justin Johnson

Calvin Mukarakate

Bryan Pivovar

David Robichaud

Daniel Ruddy

Professors Emeriti

Scott W. Cowley

Dean W. Dickerhoof

Mark E. Eberhart

Ronald W. Klusman

Donald Langmuir

Donald L. Macalady

Patrick MacCarthy

Michael J. Pavelich

Mark R. Seger

E. Craig Simmons

Kent J. Voorhees

Thomas R. Wildeman

Computer Science

Program Description

The Department of Computer Science develops graduates who can process information in digital computers, design computer hardware and software, and work successfully with several different computing applications. The department offers the degree of Bachelor of Science in Computer Science. Within this degree, a student may choose (not required) one of six available emphasis areas in Business, Computer Engineering, Data Science, Research Honors, Robotics and Intelligent Systems, or Space.

BS in Computer Science

Computing is ubiquitous, impacting almost every aspect of modern life, and playing an important role in many technological advances. Computing jobs are among the highest paid, and computing professionals generally report high job satisfaction. Graduates from our program have found employment with many different types of companies including technology, engineering, and financial companies.

The CS degree at Mines is designed to be accessible to students with or without prior programming experience. The Introduction to Computer Science course introduces students to the building blocks of CS and provides a brief introduction to procedural programming in Python. The second computing course, Programming Concepts, emphasizes development of programming skills in an object-oriented language. The third introductory course, Data Structures, provides an understanding of the classic data representation schemes, algorithms, and algorithm analysis that form the foundation for all advanced work in computing.

Required CS courses provide the fundamental skills and knowledge that are critical to success in computing. These courses reflect a mixture of theory and practice, including discrete structures, design and analysis of algorithms, principles of programming languages, computer architecture, operating systems, software engineering, and database management. The capstone field session course provides students an opportunity to work in teams to create software products for real clients.

Elective courses in CS allow students to explore a variety of important computing topics, such as graphics and visualization, artificial intelligence, mobile applications, and web programming. Elective courses often relate to recent trends in computing, covering topics such as security, high performance computing, and machine learning.

Computing is a broad field with applicability to most science and engineering domains. The CS minor is designed for students in other disciplines to receive a solid grounding in the basics, which should enable them to apply their computing skills to solve problems in other domains.

PROGRAM EDUCATIONAL OBJECTIVES (BACHELOR OF SCIENCE IN COMPUTER SCIENCE)

In addition to contributing toward achieving the educational objectives described in the Mines' Graduate Profile, the Computer Science Program at Mines has established the following program educational objectives:

Students will demonstrate technical expertise within computer science by:

- Designing and implementing solutions to practical problems in science and engineering,
- Using appropriate technology as a tool to solve problems in computer science, and
- Creating efficient algorithms and well-structured computer programs.

Students will demonstrate a breadth and depth of knowledge within computer science by:

- Extending course material to solve original problems,
- Applying knowledge of computer science to the solution of problems, and
- Identifying, formulating, and solving computer science problems.

Students will demonstrate an understanding and appreciation for the relationship of computer science to other fields by:

- Applying computer science to solve problems in other fields,
- Working in cooperative multidisciplinary teams, and
- Choosing appropriate technology to solve problems in other disciplines.

Students will demonstrate an ability to communicate computer science effectively by:

- Giving oral presentations,
- Completing written explanations,
- Interacting effectively in cooperative teams,
- Creating well-documented programs, and
- Understanding and interpreting written material in computer science.

STUDENT LEARNING OUTCOMES

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Bachelor of Science in Computer Science Degree Requirements:

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
S&W	SUCCESS AND WELLNESS			1.0
EDNS151	CORNERSTONE - DESIGN I			3.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
				15.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CSCI358	DISCRETE MATHEMATICS			3.0
CSCI210	SYSTEMS PROGRAMMING			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
MATH225	DIFFERENTIAL EQUATIONS			3.0
HASS200	GLOBAL STUDIES			3.0
FREE	Free Elective			3.0
CSCI220	DATA STRUCTURES AND ALGORITHMS			3.0

Focus Area Course 1				3.0
				15.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
MATH332	LINEAR ALGEBRA			3.0
MATH334	INTRODUCTION TO PROBABILITY			3.0
CSCI306	SOFTWARE ENGINEERING			3.0
Focus Area Course 2				3.0
Focus Area Course 3				3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective			3.0
CSCI341	COMPUTER ORGANIZATION			3.0
CSCI406	ALGORITHMS			3.0
Focus Area Course 4				3.0
				18.0

Summer		**lec**	**lab**	**sem.hrs**
CSCI370	ADVANCED SOFTWARE ENGINEERING			5.0
				5.0

Senior

Fall		**lec**	**lab**	**sem.hrs**
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
CSCI400	PRINCIPLES OF PROGRAMMING LANGUAGES			3.0
Focus Area Course 5				3.0
Focus Area Course 6				3.0
Focus Area Course 7				3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
ELECTIVE	CULTURE AND SOCIETY (CAS) 400 Level Restricted Elective			3.0
CSCI442	OPERATING SYSTEMS			3.0
Focus Area Course 8				3.0
Focus Area Course 9				3.0
Focus Area Course 10				3.0
				15.0

Total Semester Hrs: 128.0

Focus Areas

The Department of Computer Science offers seven focus areas:

1. Computer Science
2. CS + Business
3. CS + Computer Engineering
4. CS + Data Science
5. CS + Research Honors
6. CS + Robotics & Intelligent Systems
7. CS + Space

Computer Science electives can be chosen from any CSCI400-level course, any CSCI500-level course (with advisor approval), CSED435, EENG383, INNO444,or MATH307. EDNS491 and EDNS492, when both courses are taken together, can both be counted as Computer Science electives. In a given focus area, a required course for that focus area cannot also be counted as a CSCI technical elective in that focus area.

Computer Science

FREE	Free Elective	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
FREE	Free Elective	3.0
CSCI ELECT	Computer Science Elective	3.0
CSCI ELECT	Computer Science Elective	3.0
CSCI ELECT	Computer Science Elective	3.0
FREE	Free Elective	3.0
CSCI ELECT	Computer Science Elective	3.0
CSCI ELECT	Computer Science Elective	3.0
FREE	Free Elective	3.0
Total Semester Hrs		**30.0**

CS + Business

CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
EBGN***	BS Elective #&	3.0
EBGN***	BS Elective #&	3.0
EBGN***	BS Elective #&	3.0
CSCI475	INFORMATION SECURITY AND PRIVACY	3.0
CSCI ELECT	Computer Science Elective	3.0
EBGN***	BS Elective #&	3.0
CSCI448	MOBILE APPLICATION DEVELOPMENT	3.0
or CSCI445	WEB PROGRAMMING	
or CSCI446	WEB APPLICATIONS	
FREE	Free Elective	3.0
Total Semester Hrs		**30.0**

\# Four unique Business electives must be chosen from: EBGN230, EBGN280, EBGN305, EBGN320, EBGN345, EBGN346, EBGN360, EBGN381, EBGN382, E

& If a Business elective is used to satisfy the CAS restricted elective requirement, then an additional Business elective or eligible Computer Science elective must be substituted.

CS + Computer Engineering

EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER #&	3-4
or EENG282	ELECTRICAL CIRCUITS	
or PHGN215	ANALOG ELECTRONICS	
EENG284	DIGITAL LOGIC #	3-4
or PHGN317	SEMICONDUCTOR CIRCUITS- DIGITAL	
EENG383	EMBEDDED SYSTEMS	4.0
CSCI471	COMPUTER NETWORKS I	3.0
CSCI475	INFORMATION SECURITY AND PRIVACY	3.0
CSCI ELECT	Computer Science Elective	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
or CSCI440	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	
or CSCI474	INTRODUCTION TO CRYPTOGRAPHY	
CSCI/EENG ELECT	Computer Science or Electrical Engineering Elective ^	3.0
FREE	Free Elective	3.0
FREE	Free Elective	1.0
Total Semester Hrs		**29-31**

PHGN215 & PHGN317 provide similar content to EENG281 & EENG284 and both can be substituted together with preapproval.
& EENG282 may be substituted for EENG281
^ EE elective may be chosen from any EENG 400-level course

CS + Data Science

CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
MATH201	INTRODUCTION TO STATISTICS	3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH324	STATISTICAL MODELING	3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING	3.0
MATH432	SPATIAL STATISTICS	3.0
or MATH433	TIME SERIES AND ITS APPLICATIONS	
or MATH436	ADVANCED STATISTICAL MODELING	
or MATH437	MULTIVARIATE ANALYSIS	
or MATH438	STOCHASTIC MODELS	
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
or CSCI423	COMPUTER SIMULATION	
or CSCI440	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	
or CSCI474	INTRODUCTION TO CRYPTOGRAPHY	
or CSCI475	INFORMATION SECURITY AND PRIVACY	
CSCI ELECT	Computer Science Elective	3.0
FREE	Free Elective	3.0
Total Semester Hrs		**30.0**

CS + Research Honors

FREE	Free Elective	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
CSCI ELECT	Computer Science Elective	3.0
CSCI480	COMPUTER SCIENCE HONORS THESIS	3.0
CSCI5**	Computer Science Honors Elective #	3.0
CSCI ELECT	Computer Science Elective	3.0
CSCI480	COMPUTER SCIENCE HONORS THESIS	3.0
CSCI5**	Computer Science Honors Elective #	3.0
CSCI ELECT	Computer Science Elective	3.0
Total Semester Hrs		**30.0**

Computer Science Honors electives may be any CSCI500-level course approved by advisor.

CS + Robotics & Intelligent Systems

EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER #&	3-4
or EENG282	ELECTRICAL CIRCUITS	
or PHGN215	ANALOG ELECTRONICS	
FREE	Free Elective	3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI437	INTRODUCTION TO COMPUTER VISION	3.0
or CSCI473	ROBOT PROGRAMMING AND PERCEPTION	
CSCI470	INTRODUCTION TO MACHINE LEARNING	3.0
or CSCI534	ROBOT PLANNING AND MANIPULATION	
CSCI432	ROBOT ETHICS	3.0
or CSCI436	HUMAN-ROBOT INTERACTION	
CSCI473	ROBOT PROGRAMMING AND PERCEPTION	3.0
or CSCI432	ROBOT ETHICS	
or CSCI436	HUMAN-ROBOT INTERACTION	
or CSCI437	INTRODUCTION TO COMPUTER VISION	
or CSCI470	INTRODUCTION TO MACHINE LEARNING	
or CSCI534	ROBOT PLANNING AND MANIPULATION	
CSCI ELECT	Computer Science Elective	3.0
Total Semester Hrs		**30-31**

PHGN215 provides similar content to EENG281 and can be substituted with preapproval
& EENG282 may be substituted for EENG281

CS + Space

EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER #&	3.0
or EENG282	ELECTRICAL CIRCUITS	

or PHGN215	ANALOG ELECTRONICS	
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
or CSCI404	ARTIFICIAL INTELLIGENCE	
or CSCI475	INFORMATION SECURITY AND PRIVACY	
FREE	Free Elective	3.0
EENG284	DIGITAL LOGIC #	4.0
or PHGN317	SEMICONDUCTOR CIRCUITS- DIGITAL	
MEGN452	INTRO TO SPACE EXPLORATION AND RESOURCES	3.0
MEGN455	AEROSPACE SYSTEMS ENGINEERING	3.0
MEGN456	SPACE OPERATIONS AND MISSION DESIGN	3.0
CSCI423	COMPUTER SIMULATION	3.0
or CSCI440	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	
or CSCI471	COMPUTER NETWORKS I	
EENG383	EMBEDDED SYSTEMS	4.0
CSCI***	CS Elective	3.0

PHGN215 & PHGN317 provide similar content to EENG281 & EENG284 and both can be substituted together with preapproval.

& EENG282 may be substituted for EENG281

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- CSCI200 through CSCI799 inclusive, excluding CSCI*99

Computer Science

For a **Minor in Computer Science,** the student needs to take:

CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN	3.0
CSCI210	SYSTEMS PROGRAMMING	3.0
CSCI220	DATA STRUCTURES AND ALGORITHMS	3.0
CSCI358	DISCRETE MATHEMATICS	3.0
or MATH334	INTRODUCTION TO PROBABILITY	
CSCI306	SOFTWARE ENGINEERING *	3.0
	or CSCI Elective	
CSCI ELECT	Computer Science Elective *	3.0

* CSCI electives can be chosen from any 400-level or 500-level CSCI course, MATH307, and EENG383.

Minor in Computer Engineering

To earn the Minor in Computer Engineering, a student must take at least 18 credits from the following list, at least 9 of which must be 300-level or above:

CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN	3.0
CSCI210	SYSTEMS PROGRAMMING	3.0
CSCI220	DATA STRUCTURES AND ALGORITHMS	3.0
CSCI341	COMPUTER ORGANIZATION	3.0
CSCI442	OPERATING SYSTEMS	3.0
EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER ^	3.0
or EENG282	ELECTRICAL CIRCUITS	
EENG284	DIGITAL LOGIC *	4.0
EENG383	EMBEDDED SYSTEMS	4.0

^ PHGN215 may be used in place of EENG281/EENG282 with pre-approval by the student's major program director.

* PHGN317 may be used in place of EENG284 with pre-approval by the student's major program director.

At most 6.0 credits of this minor can be counted toward another minor degree program.

Minor in Data Science

Complete one of the following sets of courses:

CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN	3.0
CSCI220	DATA STRUCTURES AND ALGORITHMS	3.0
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
MATH201	INTRODUCTION TO STATISTICS	3.0
Choose 2 of		
CSCI403	DATA BASE MANAGEMENT	6.0
or CSCI404	ARTIFICIAL INTELLIGENCE	
or CSCI470	INTRODUCTION TO MACHINE LEARNING	
or CSCI478	INTRODUCTION TO BIOINFORMATICS	
Total Semester Hrs		**18.0**

Or

CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN	3.0
CSCI220	DATA STRUCTURES AND ALGORITHMS	3.0
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
MATH201	INTRODUCTION TO STATISTICS	3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
Total Semester Hrs		**18.0**

Minor in Robotics and Intelligent Systems

Complete the following courses:

CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN	3.0

CSCI220	DATA STRUCTURES AND ALGORITHMS	3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
or CSCI437	INTRODUCTION TO COMPUTER VISION	
or CSCI470	INTRODUCTION TO MACHINE LEARNING	
CSCI473	ROBOT PROGRAMMING AND PERCEPTION	3.0
or CSCI436	HUMAN-ROBOT INTERACTION	
or CSCI534	ROBOT PLANNING AND MANIPULATION	
Total Semester Hrs		**18.0**

Courses

CSCI101. INTRODUCTION TO COMPUTER SCIENCE. 3.0 Semester Hrs.
Introduction to Computer Science is a 3-credit hour **breadth** CS course. We cover several topics in this course to help students understand how computers work, e.g., binary numbers, Boolean logic and gates, circuit design, machine language, computer hardware, assembly, operating systems, networking, the Internet protocols, cybersecurity, data science, machine learning, and robotics.
Course Learning Outcomes

- 1. Demonstrate how data is represented in computers
- 2. Define the building blocks and organization of computer hardware
- 3. Describe the differences between machine, assembly, and high-level languages
- 4. Design an efficient algorithm and analyze its time/space complexity
- 5. Implement algorithms that solve problems
- 6. Explain how the Internet works
- 7. Detail how an operating system manages processes
- 8. Evaluate whether one is keeping data private
- 9. Categorize the different threats to computer systems
- 10. Perform the data science process
- 11. Explain the Turing test and how one defines intelligence
- 12. Categorize the different types of machine learning algorithms
- 13. Describe key computer ethics topics
- 14. Recognize the impact of computing on the world
- 15. Design and program Python applications,
- 16. Write loops and decision statements in Python,
- 17. Use lists, tuples, sets, dictionaries, and strings in Python,
- 18. Define the structure/components of a Python program,
- 19. Write functions and pass arguments in Python,
- 20. Write code that reads/writes files in Python,
- 21. Design object-oriented programs with Python classes, and
- 22. Read (trace) basic Python code.

CSCI102. INTRODUCTION TO COMPUTER SCIENCE - LAB. 1.0 Semester Hr.
CSCI 102 is our Introduction to Computer Science LAB course. CSCI 102 is a 1-credit hour programming course in Python that is (A) extremely valuable for those who have never programmed and (B) required for some majors (e.g., MechE). While CSCI 102 is not required for some majors, students with little (or no) prior programming experience are strongly encouraged to enroll.
Course Learning Outcomes

- Design and program Python applications
- Write loops and decision statements in Python
- Use lists, tuples, sets, dictionaries, and strings in Python
- Define the structure/components of a Python program
- Write functions and pass arguments in Python
- Write code that reads/writes files in Python
- Design object-oriented programs with Python classes
- Read (trace) basic Python code

CSCI128. COMPUTER SCIENCE FOR STEM. 3.0 Semester Hrs.
Introduction to programming. Intended for students with no prior experience. Teaches basic programming constructs including data types, conditionals, loops, file I/O, functions, and objects in Python 3. Also covers topics vital to STEM computing, such as data science, best practices for code development, and software ethics. Prerequisite: None Co-requisite: None.
Course Learning Outcomes

- 1. Analyze a simple empirical problem, break it down into smaller more manageable components, and design algorithmic solutions to these subproblems
- 2. Implement an existing prompt, plan, or design into programmatically correct Python code that produces the expected text, file, or graph output
- 3. Communicate in the language of programming with a computer and other programmers through code reading, writing, and critique
- 4. Critically discuss and reflect on the role technology has in modern society, and the positive and negative impacts their software may have on future users
- 5. Model how basic numeric and non-numeric data is represented in a computer; identify when, why, and how these physical representations diverge from their conceptual equivalents
- 6. Navigate and utilize a computer file system through a GUI, the text console, and code
- 7. Demonstrate effective debugging practices in an IDE to find, characterize, and correct code errors

CSCI195. CS@MINES BRIDGE SEMINAR COURSE. 1.0 Semester Hr.
The purpose of this course is to support Bridge students for success in CS@Mines. Through this course, students will: 1. Engage in activities that show how computing changes the world and impacts daily lives, 2. Delve into a some of the foundational computer science topics (e.g., Binary Numbers, Networking, Operating Systems, Cybersecurity, Cyber Physical Systems, Artificial Intelligence, Machine Learning, Data Science, Bioinformatics, Robotics), and 3. Explore different career paths in the computer science industry. Most importantly, this course will offer students the opportunity to build relationships with their cohort and their program advisors (e.g., Bridge Program Director, Graduate Program Manger), as well as be a source of strength for each other. Prerequisite: Current CS@Mines Bridge Student .
Course Learning Outcomes

- 1. Describe a breadth of foundational computer science topics and how they relate to emphasis areas in computing.
- 2. Implement networking and relationship building techniques within their cohort and other like-minded students.
- 3. Explain the importance of personal development tools and preparedness for careers in computing (e.g., imposter syndrome, the elevator pitch, resume building, navigating career day).

- 4. Summarize the different types of careers that exist in the computer science field.
- 5. Analyze the specific fields in computer science that are of most interest for deeper exploration and potential degree focus area.

CSCI198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI200. FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN. 3.0 Semester Hrs.
This course teaches students C++, how to manage memory properly & efficiently at run time, the principles of object-oriented programming, and how to create an algorithm using data structures & abstraction to solve a problem. Recursive data structures & algorithms will be constructed & analyzed when solving problems. Initial principal components of software engineering and design will be introduced and used when drafting a solution to a problem. Programs will be developed using a command line interface. Prerequisite: CSCI101 or CSCI128.
Course Learning Outcomes

- L1. Design an algorithm to solve a problem by breaking the overarching problem into smaller modular components using abstraction and object-oriented design with inheritance.
- L2. Translate the algorithm into a program using proper C++ syntax and fundamental programming constructs (e.g. control structures, I/O, classes).
- L3. Recite & apply frequently used Linux command line commands and compile a program using a command line build system.
- L4. Diagram memory usage, dynamically allocate & deallocate objects at run-time using "The Big Three," and trace the call stack of a program’s run-time.
- L5. Define recursion and construct common recursive data structures (e.g. linked list, stack, queue) & algorithms (e.g. search & sort).
- L6. Diagram & construct dynamically allocated data structures (e.g. array, vector, string), recursive data structures, (e.g. linked list, stack, queue), and implement common list operations (e.g. traversal, insertion, removal)
- L7. Define "Big-O" notation, list complexities in increasing order, and analyze an algorithm to compute its run-time performance & memory complexities

CSCI210. SYSTEMS PROGRAMMING. 3.0 Semester Hrs.
The Systems Programming course will teach students how to become proficient with using a Linux operating system from the command line and programming Linux systems. Topics will include: shell scripts; compiling and linking programs; redirecting input and output; controlling jobs from the command line; using advanced SSH functions such as port forwarding and dynamic proxying; file system hierarchy;, package management; kernel compilation; network management; C programming with dynamic memory management, function pointers, c-style polymorphism, recursive functions, and data structures; learning how to use a code repository maintenance tool, such as git, from the command line effectively; security, privacy, and encryption concepts; inter-process communication and client-server architectures. Prerequisite: CSCI200.
Course Learning Outcomes

- 1. Identify, select, and apply appropriate Linux commands for file, process, and network management.
- 2. Utilize the command line by designing and creating shell scripts; compiling and linking programs; redirecting input and output of processes; and executing commands for controlling jobs/processes.
- 3. Explain the purpose of and apply advanced SSH functions such as port forwarding, dynamic proxying, effectively.
- 4. Administer a Linux system applying knowledge of the file system hierarchy, package management, kernel compilation, and network management.
- 5. Design and write C programs composed of dynamic memory management, function pointers, c-style polymorphism, recursive functions, and data structures.
- 6. Examine the capabilities of a code repository maintenance tool, such as git, through command line version control.
- 7. Select and implement appropriate security, privacy, and encryption protocols at the operating system level.
- 8. Design and implement programs with client-server architecture using inter-process communication.
- 9. Discuss and apply appropriate time and project management strategies through the development of multiple substantial programming projects throughout the semester.

CSCI220. DATA STRUCTURES AND ALGORITHMS. 3.0 Semester Hrs.
This course teaches students the design and construction of data structures such as hash tables, trees, heaps, and graphs, analysis of operations on data structures, and design and analysis of algorithms on data structures such as graph search and minimum spanning tree algorithms. Applications of data structures and algorithms on them are discussed in the context of computer systems. Students will further refine programming skills in C++ by producing software implementations of selected data structures and algorithms. Prerequisite: CSCI200 with a C- or better, CSCI358 or MATH334.
Course Learning Outcomes

- L1. Perform time and space complexity analyses of algorithms, including sorting and searching algorithms and operations on data structures such as hash tables, trees, graphs, and strings.
- L2. Implement fundamental data structures and algorithms in a high-level programming language.
- L3. Prepare analysis reports detailing theoretical and empirical studies of algorithms and data structures.
- L4. Evaluate and select data structures and algorithms for computing applications such as sorting, indexing, string searching and pattern matching, and path finding.
- L5. Explain and illustrate the function of array-based data structures (dynamic arrays, hash tables, and strings) and algorithms applied to arrays (sorting, searching and pattern matching).
- L6. Explain and illustrate the function of linked data structures (linked lists, trees, and graphs) and algorithms on those data structures.

CSCI250. PYTHON-BASED COMPUTING: BUILDING A SENSOR SYSTEM. 3.0 Semester Hrs.
This course will teach students the skills needed for data collection, analysis, and visualization on a small embedded device (e.g., Raspberry Pi). Students will learn basic Linux, Python, and the programming skills needed to control the hardware and associated sensors. This hands-on course includes a baseline project, four introductory projects (e.g., acoustic, acceleration, magnetic field, optical), and a final Capstone project. The Capstone project will have students create their own application using the techniques learned during the first half of the semester; students will then present their Capstone project through a formal presentation, write-up, and demonstration. We suggest the student take "Introduction to Computer Science" before this course. Prerequisite: CSCI128. Co-requisite: MATH213, PHGN200.
Course Learning Outcomes

- 1. Create, navigate, and manage files and directory structures using basic Linux shell commands.
- 2. Describe the functionality and purpose of the individual components of the Raspberry Pi Hardware.
- 3. Install the Raspian operating system onto the Raspberry Pi Hardware and setup basic configuration parameters.
- 4. Download, install, and develop programs using the Spyder Integrated Development Environment (IDE) on the Raspberry Pi Hardware.
- 5. Develop and run basic Python functions and programs in the Linux environment to collect data from sensors using the Raspberry Pi Hardware (e.g., acoustic, acceleration, magnetic field, optical).
- 6. Plot and analyze data from the sensor system and compare to mathematical models.

CSCI260. FORTRAN PROGRAMMING. 2.0 Semester Hrs.
(I) Computer programming in Fortran90/95 with applications to science and engineering. Program design and structure, problem analysis, debugging, program testing. Language skills: arithmetic, input/output, branching and looping, functions, arrays, data types. Introduction to operating systems. Prerequisite: none. 2 hours lecture; 2 semester hours.

CSCI261. PROGRAMMING CONCEPTS. 3.0 Semester Hrs.
This course introduces fundamental computer programming concepts using a high-level language and a modern development environment. Programming skills include sequential, selection, and repetition control structures, functions, input and output, primitive data types, basic data structures including arrays and pointers, objects, and classes. Software engineering skills include problem solving, program design, and debugging practices. Prerequisite: CSCI101.
Course Learning Outcomes

- unchanged

CSCI262. DATA STRUCTURES. 3.0 Semester Hrs.
Defining and using data structures such as linked lists, stacks, queues, binary trees, binary heap, and hash tables. Introduction to algorithm analysis, with emphasis on sorting and search routines. Language skills: abstract data types, templates, and inheritance. 3 hours lecture; 3 semester hours. Prerequisite: CSCI261 with a grade of C- or higher or CSCI200 with a grade of C- or higher.
Course Learning Outcomes

- unchanged

CSCI274. INTRODUCTION TO THE LINUX OPERATING SYSTEM. 1.0 Semester Hr.
Introduction to the Linux Operating System will teach students how to become proficient with using a Linux operating system from the command line. Topics will include: remote login (ssh), file system navigation, file commands, editors, compilation, execution, redirection, output, searching, processes, usage, permissions, compression, parsing, networking, and bash scripting. Prerequisite: CSCI200 or CSCI261.
Course Learning Outcomes

- unchanged

CSCI290. PROGRAMMING CHALLENGES I. 1.0 Semester Hr.
This course is the first of three courses in the Programming Challenges sequence which covers problem solving patterns and paradigms found in technical interviews and programming competitions. The students will learn more advanced data structures and algorithms while focusing on algorithmic complexity to solve problems in a finite amount of time. Co-requisite: CSCI220 or CSCI262.
Course Learning Outcomes

- Solve common programming problems and identify underlying patterns
- Argue and prove correctness of solution
- Determine and argue space and time complexity of solutions
- Combine common algorithms to solve problems
- Improve skills in technical interviews and programming competitions

CSCI295. INDUSTRY EXPLORATION I. 1.0 Semester Hr.
Industry Exploration I provides 1st and 2nd year students an opportunity to explore different career paths in computer science. Each week students meet (over Zoom) with a company that hires a number of computer scientists. Prior to the meeting, students research the company and determine 1-2 specific question(s) to ask during the meeting (i.e., questions specific to the company). During the meeting, students talk with employees at the company to learn more about the types of computer science jobs that exist. After the meeting, students reflect on what was learned during the meeting. At the end of the semester, students have a better understanding of different types of jobs in computer science and what they may want to do in their future careers.
Course Learning Outcomes

- 1. Understand different types of companies that hire CS majors through their research and visits with the companies
- 2, Have answers to questions they have generated, to further their understanding of positions and roles in CS industry
- 3. Improve their professional communication and networking skills through experience
- 4. Shape their future career path by relating what they learn in the course

CSCI298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must

be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI303. INTRODUCTION TO DATA SCIENCE. 3.0 Semester Hrs.
This course will teach students the core skills needed for gathering, cleaning, organizing, analyzing, interpreting, and visualizing data. Students will learn basic SQL for working with databases, basic Python programming for data manipulation, and the use and application of statistical and machine learning toolkits for data analysis. The course will be primarily focused on applications, with an emphasis on working with real (non-synthetic) datasets. Prerequisite: CSCI101 or CSCI102 or CSCI128.
Course Learning Outcomes

- 1. Acquire, clean, and organize data from a variety of sources, including raw data files, SQL databases, and online repositories.
- 2. Run simple SQL queries to manipulate and analyze data in relational databases and other data stores implementing SQL front ends.
- 3. Apply toolkits to preprocess large datasets for input to statistical and machine learning algorithms, including methods of feature extraction and dimensionality reduction.
- 4. Apply statistical and machine learning toolkits to large datasets, including applications of regression, classification, and clustering.
- 5. Perform simple visualizations of data.
- 6. Recognize and address the ethical issues arising from data collection and statistical and machine learning.

CSCI306. SOFTWARE ENGINEERING. 3.0 Semester Hrs.
Introduction to software engineering processes and object-oriented design principles. Topics include the Agile development methodology, test-driven development, UML diagrams, use cases and several object-oriented design patterns. Course work emphasizes good programming practices via version control and code reviews. Prerequisite: CSCI210 with grade of C- or higher, CSCI220 with grade of C- or higher or CSCI262 with grade of C- or higher.
Course Learning Outcomes

- unchanged

CSCI340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I, II, S) (WI) Supervised, full-time engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions. Repeatable.

CSCI341. COMPUTER ORGANIZATION. 3.0 Semester Hrs.
Covers the basic concepts of computer architecture and organization. Topics include machine level instructions and operating system calls used to write programs in assembly language, computer arithmetics, performance, processor design, and pipelining techniques. This course provides insight into the way computers operate at the machine level. Prerequisite: CSCI200 OR CSCI210 OR (CSCI261 AND CSCI262).
Course Learning Outcomes

- unchanged

CSCI358. DISCRETE MATHEMATICS. 3.0 Semester Hrs.
This course is an introductory course in discrete mathematics and algebraic structures. Topics include: formal logic; proofs, recursion, analysis of algorithms; sets and combinatorics; relations, functions, and matrices; Boolean algebra and computer logic; trees, graphs, finite-state machines, and regular languages. Prerequisite: MATH112 or MATH122.
Course Learning Outcomes

- unchanged

CSCI370. ADVANCED SOFTWARE ENGINEERING. 5.0 Semester Hrs.
This capstone course has three primary goals: (1) to enable students to apply their course work knowledge to a challenging applied problem for a real client, (2) to enhance students' verbal and written communication skills, and (3) to provide an introduction to ethical decision making in computer science. Ethics and communication skills are emphasized in a classroom setting. The client work is done in small teams, either on campus or at the client site. Faculty advisors provide guidance related to the software engineering process, which is similar to Scrum. By the end of the course students must have a finished product with appropriate documentation. Prerequisite: CSCI306.
Course Learning Outcomes

- unchanged

CSCI390. PROGRAMMING CHALLENGES II. 1.0 Semester Hr.
This course is the second of three courses in the Programming Challenges sequence which covers problem solving patterns and paradigms found in technical interviews and programming competitions. The students will learn more advanced set, counting, & number theory and algorithms while focusing on algorithmic complexity to solve problems in a finite amount of time. Prerequisite: CSCI290. Co-requisite: CSCI358.
Course Learning Outcomes

- Solve common programming problems and identify underlying patterns
- Argue and prove correctness of solution
- Determine and argue space and time complexity of solutions
- Combine common algorithms to solve problems
- Improve skills in technical interviews and programming competitions

CSCI395. INDUSTRY EXPLORATION II. 1.0 Semester Hr.
Industry Exploration II provides 3rd and 4th year students an opportunity to explore different career paths in computer science. Each week students visit a company that hires a number of computer scientists at the company?s office. Prior to the visit, students research the company and determine 1-2 specific question(s) to ask during the meeting (i.e., questions specific to the company). During the visit, students are provided a tour of the company?s office and the opportunity to talk to employees and learn more about the types of computer science jobs that exist. After the visit, students reflect on what was learned during the visit. At the end of the semester, students have a better understanding of different types of jobs in computer science and what they may want to do in their future careers.
Course Learning Outcomes

- 1. Understand different types of companies that hire CS majors through their research and visits with the companies
- 2. Have answers to questions they have generated, to further their understanding of positions and roles in CS industry
- 3. Improve their professional communication and networking skills through experience
- 4. Discover different company cultures / work environments

- 5. Shape their future career path by relating what they learn in the course

CSCI398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI400. PRINCIPLES OF PROGRAMMING LANGUAGES. 3.0 Semester Hrs.
This course takes a broad view of programming languages, focusing on the fundamental abstractions and principles of language design that transcend the specifics of any particular programming language. The course will emphasize functional programming, develop experience via programming projects, and cover topics such as lambda calculus, higher-order functions, induction, persistence, type systems, syntax, and evaluation. Ultimately, students will have an opportunity to improve programming skills, and develop a deeper understanding of how programming languages are designed and implemented. Prerequisite: CSCI306, CSCI358.
Course Learning Outcomes

- unchanged

CSCI403. DATA BASE MANAGEMENT. 3.0 Semester Hrs.
Design and evaluation of information storage and retrieval systems, including defining and building a database and producing the necessary queries for access to the stored information. Relational database management systems, structured query language, and data storage facilities. Applications of data structures such as lists, inverted lists and trees. System security, maintenance, recovery and definition. Interfacing host languages to database systems and object-relational mapping tools. NoSQL databases and distributed databases. Prerequisite: CSCI200 with a grade of C- or higher or CSCI262 with a grade of C- or higher.
Course Learning Outcomes

- unchanged

CSCI404. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.
General investigation of the Artificial Intelligence field. Several methods used in artificial intelligence such as search strategies, knowledge representation, logic and probabilistic reasoning are developed and applied to practical problems. Fundamental artificial intelligence techniques are presented, including neural networks, genetic algorithms, and fuzzy sets. Selected application areas, such as robotics, natural language processing and games, are discussed. Prerequisite: (CSCI220 with a grade of C- or higher or CSCI262 with a grade of C- or higher) and (MATH201 or MATH334).
Course Learning Outcomes

- n/a

CSCI406. ALGORITHMS. 3.0 Semester Hrs.
Equivalent with MATH406,
Reasoning about algorithm correctness (proofs, counterexamples). Analysis of algorithms: asymptotic and practical complexity. Review of dictionary data structures (including balanced search trees). Priority queues. Advanced sorting algorithms (heapsort, radix sort). Advanced algorithmic concepts illustrated through sorting (randomized algorithms, lower bounds, divide and conquer). Dynamic programming. Backtracking. Algorithms on unweighted graphs (traversals) and weighted graphs (minimum spanning trees, shortest paths, network flows and bipartite matching); NP-completeness and its consequences. Prerequisite: CSCI220 with a grade of C- or higher or CSCI262 with a grade of C- or higher, MATH213 or MATH223, MATH300 or MATH358 or CSCI358.
Course Learning Outcomes

- Reasoning about algorithm correctness (proofs, counterexamples)
- Analysis of algorithms

CSCI410. ELEMENTS OF COMPUTING SYSTEMS. 3.0 Semester Hrs.
This comprehensive course will help students consolidate their understanding of all fundamental computer science concepts. Topics include symbolic communication, Boolean logic, binary systems, logic gates, computer architecture, assembly language, assembler construction, virtual machines, object-oriented programming languages, software engineering, compilers, language design, and operating systems. Using a hardware simulator and a programming language of their choice, students construct an entire modern computer from the ground up, resulting in an intimate understanding of how each component works. Prerequisites: CSCI341 or EENG383. 3 lecture hours, 3 credit hours.

CSCI422. USER INTERFACES. 3.0 Semester Hrs.
User Interface Design is a course for programmers who want to learn how to create more effective software. This objective will be achieved by studying principles and patterns of interaction design, critiquing existing software using criteria presented in the textbooks, and applying criteria to the design and implementation of one larger product. Students will also learn a variety of techniques to guide the software design process, including Cognitive Walkthrough, Talk-aloud and others. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI423. COMPUTER SIMULATION. 3.0 Semester Hrs.
A first course in computer simulation using formal learning groups and emphasizing the rigorous development of simulation applications. Topics will include random number generation, Monte Carlo simulation, discrete event simulation, and the mathematics behind their proper implementation and analysis (random variates, arrival time modeling, infinite horizon statistics, batch means and sampling techniques). The course uses learning group assignments, quizzes, programming projects (using Linux) and exams for assessment. Prerequisite: (CSCI210 or CSCI274) AND CSCI306 AND (MATH201 or MATH334).
Course Learning Outcomes

- All.
- All.
- Simulation software design and implementation.
- Simulation software design and implementation.
- Individual "Student Bounties" in simulation, results of journaled communications.

CSCI425. COMPILER DESIGN. 3.0 Semester Hrs.
An introductory course to the design and construction of compilers. Topics include scanning (lexical analysis), context free grammars, recursive descent (top-down) parsing, LR (bottom up) parsing, syntax directed translation, syntax trees, expression trees, parse trees, intermediate representation, register allocation and target code generation. Students will construct their own tool chain for compiling a

simple language, tracking the relevant course topics as they are covered. Prerequisite: CSCI306 AND CSCI341.
Course Learning Outcomes

- 1. Understand the steps taken by most compilers to translate a program listing to either another language or target code for a machine.
- 2. Understand and be able to apply the theory of lexical analysis, regular expressions, deterministic finite automata (DFAs), non-deterministic finite automata (NFAs), and how to use scanner generators (eg flex).
- 3. Know the fundamental principles of context free grammars as well as their associated attributes and properties.
- 4. Understand the constructs for expressing operator precedence and associativity in context free grammars, as well as how language ambiguities are detected and worked around by modern compiler tools.
- 5. Know the theory and implementation of top-down and bottom up parsing, the generation of parse trees, and their translation to abstract syntax trees (ASTs).
- 6. Know program statements are translated to machine language at the CPU op-code and register level.

CSCI432. ROBOT ETHICS. 3.0 Semester Hrs.
This course explores ethical issues arising in robotics and human-robot interaction through philosophical analysis, behavioral and psychological analysis, research ethics education, and the integration of social and ethical concerns in scientific experimentation and algorithm design. Topics include case studies in lethal autonomous weapon systems, autonomous cars, and social robots, as well as higher-level concerns including economics, law, policy, and discrimination. Prerequisite: CSCI200 and MATH201.
Course Learning Outcomes

- 1. Understand the basic ethical theories, concepts, tools, and frameworks for analyzing the social and ethical ramifications of robotics
- 2. Be able to critically examine the ethical significance of the use of robotics in daily and technical fields including human-robot interaction, medicine, relationship, military, etc.
- 3. Develop a critical attitude toward the role of robotics in shaping human society including human perceptions and behaviors
- 4. Be able to use the theories, concepts, tools, and frameworks learned from this class to critically examine emerging robot ethics issues in the society.
- 4. Understand the tradeoffs underlying the design of autonomous moral agents

CSCI436. HUMAN-ROBOT INTERACTION. 3.0 Semester Hrs.
Human-Robot Interaction is an interdisciplinary field at the intersection of Computer Science, Robotics, Psychology, and Human Factors, that seeks to answer a broad set of questions about robots designed to interact with humans (e.g., assistive robots, educational robots, and service robots), such as: (1) How does human interaction with robots differ from interaction with other people? (2) How does the appearance and behavior of a robot change how humans perceive, trust, and interact with that robot? And (3) How can we design and program robots that are natural, trustworthy, and effective? Accordingly, In this course, students will learn (1) how to design interactive robots, (2) the algorithmic foundations of interactive robots; and (3) how to evaluate interactive robots. To achieve these learning objectives, students will read and present key papers from the HRI literature, and complete a final project in which they will design, pilot, and evaluate novel HRI experiments in small groups, with in-class time expected to be split between lecture by the instructor, presentations by students, and either collaborative active learning activities or discussions with researchers in the field. Prerequisite: CSCI200 or CSCI262 and MATH201 or MATH334.
Course Learning Outcomes

- 1. Understand the theoretical foundations and critical application domains of human-robot interaction.
- 2. Employ design techniques to design interactive robots.
- 3. Design human-subject experiments to evaluate interactive robots.
- 4. Perform qualitative and quantitative analysis on the results of human-robot interaction experiments.

CSCI437. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI512,EENG507,EENG512,
Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. Must be Senior level standing. 3 hours lecture; 3 semester hours. Prerequisite: (MATH201 or MATH334 or EENG311) and MATH332 and (CSCI200 or CSCI261).
Course Learning Outcomes

- 1. Be able to analyze and predict the behavior of image formation, transformation, and recognition algorithms.
- 2. Be able to design, develop, and evaluate algorithms for specific applications.
- 3. Be able to use software tools to implement computer vision algorithms.

CSCI440. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.
Equivalent with MATH440,
This course is designed to introduce the field of parallel computing to all scientists and engineers. The students will be taught how to solve scientific problems using parallel computing technologies. They will be introduced to basic terminologies and concepts of parallel computing, learn how to use MPI to develop parallel programs, and study how to design and analyze parallel algorithms. Prerequisite: CSCI220 with a grade of C- or higher or CSCI262 with a grade of C- or higher, CSCI341.
Course Learning Outcomes

- To follow

CSCI441. COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with MATH441,
This class focuses on the basic 3D rendering and modeling techniques. In particular, it covers the graphics pipeline, elements of global illumination, modeling techniques based on polynomial curves and patches, and shader programming using the GPU. Prerequisite: CSCI220 with a grade of C- or higher or CSCI262 with a grade of C- or higher, MATH332.
Course Learning Outcomes

- Describe, replicate, & modify the graphical pipeline
- Create interactive, real-time graphics applications

CSCI442. OPERATING SYSTEMS. 3.0 Semester Hrs.
Introduces the essential concepts in the design and implementation of operating systems: what they can do, what they contain, and how they are implemented. Despite rapid OS growth and development, the fundamental concepts learned in this course will endure. We will cover the following high-level OS topics, roughly in this order: computer systems, processes, processor scheduling, memory management, virtual memory, threads, and process/thread synchronization. This course provides insight into the internal structure of operating systems; emphasis is on concepts and techniques that are valid for all computers. Prerequisite: (CSCI 220 with a grade of C- or higher OR CSCI 262 with a grade of C- or higher) AND CSCI341.
Course Learning Outcomes

- n/a

CSCI443. ADVANCED PROGRAMMING CONCEPTS USING JAVA. 3.0 Semester Hrs.
This course will quickly review programming constructs using the syntax and semantics of the Java programming language. It will compare the constructs of Java with other languages and discuss program design and implementation. Object oriented programming concepts will be reviewed and applications, applets, servlets, graphical user interfaces, threading, exception handling, JDBC, and network - ing as implemented in Java will be discussed. The basics of the Java Virtual Machine will be presented. 3 hours lecture, 3 semester hours Prerequisite: CSCI306.

CSCI444. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with MATH444,
This is an advanced computer graphics course, focusing on modern rendering and geometric modeling techniques. Students will learn a variety of mathematical and algorithmic techniques that can be used to develop high-quality computer graphic software. Runtime performance will be evaluated to create optimized real-time graphics applications. In particular, the course will cover global illumination, GPU programming, and virtual and augmented reality. Prerequisites: CSCI441. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Describe, replicate, and modify the modern advanced graphics pipeline
- Create a real-time graphics application using an advanced graphics technique

CSCI445. WEB PROGRAMMING. 3.0 Semester Hrs.
Web Programming is a course for programmers who want to develop web-based applications. It covers basic website design extended by client-side and server-side programming. Students should acquire an understanding of the role and application of web standards to website development. Topics include Cascading Style Sheets (CSS), JavaScript, PHP and database connectivity. At the conclusion of the course students should feel confident that they can design and develop dynamic Web applications on their own. Prerequisite: CSCI306. Co-requisite: CSCI403.
Course Learning Outcomes

- 1. Students will be able to apply software engineering skills to develop an interactive website.
- 2. Students will have an understanding of the dominant web architecture (REST).

CSCI446. WEB APPLICATIONS. 3.0 Semester Hrs.
In Web Applications students will learn how to build effective web-based applications. At the completion of this course, students should know HTTP, Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript, Ajax, and RESTful architectures. Additionally students should have considered a variety of issues related to web application architecture, including but not limited to security, performance, web frameworks and cloud-based deployment environments. 3 hours lecture; 3 semester hours. Prerequisite: CSCI220 or CSCI262. Co-requisite: CSCI403.
Course Learning Outcomes

- n/a

CSCI448. MOBILE APPLICATION DEVELOPMENT. 3.0 Semester Hrs.
This course covers basic and advanced topics in mobile application development. Topics include the mobile application lifecycle, user interface components and layouts, storing persistent data, accessing network resources, using location and sensor APIs including GPS and accelerometer, starting and stopping system services, and threading. This is a project-based course where students will design and develop complete applications. Prerequisite: CSCI306 with a grade of C- or higher. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- unchanged

CSCI455. GAME THEORY AND NETWORKS. 3.0 Semester Hrs.
Equivalent with CSCI555,
An introduction to fundamental concepts of game theory with a focus on the applications in networks. Game theory is the study that analyzes the strategic interactions among autonomous decision-makers. Originated from economics. Influenced many areas in Computer Science, including artificial intelligence, e-commerce, theory, and security and privacy. Provides tools and knowledge for modeling and analyzing real-world problems. Prerequisites: CSCI358, CSCI406. 3 hours lecture; 3 semester hours.

CSCI460. SOFTWARE STARTUPS: FROM IDEA TO LAUNCH. 3.0 Semester Hrs.
This course is intended for students who wish to first-hand experience what it takes to get a software idea off the ground. You may already have an idea, or along with classmates, can choose from one of the course?s prefabricated ideas. You will learn how to test your idea with real market feedback ? you will interview potential users, develop user stories, design wireframes (skeletal frameworks that help visualize one?s idea), develop and launch a working beta product, and subsequently iterate on your product with user feedback to continue to refine and drive user adoption. You will learn different go-to-market strategies and gain a deeper understanding of your market. In addition, this course places a real emphasis on interpersonal dynamics and driving to founder-level productivity. Through interactive role-plays, perspective-taking drills, and frameworks for how to give and receive feedback without being hurtful, students will learn how to effectively work together as part of a team. This course is experiential and requires a technical background and strong software development skills to take an idea and implement a hands-on solution over the course of the term. Prerequisite: CSCI306.
Course Learning Outcomes

- In the context of a problem that the student sets out to solve, synthesize the pain of target users through conducting user interviews.
- Create wireframes based on insights from user interactions.

- Develop and launch a working beta product based on user needs.
- Engage in a feedback loop with users to refine their product and drive user adoption.
- Foster high performance in teams by developing proficiency in feedback mechanisms.
- Develop mastery of storytelling in the context of software startup ventures.

CSCI470. INTRODUCTION TO MACHINE LEARNING. 3.0 Semester Hrs.
The goal of machine learning is to build computer systems that improve automatically with experience, which has been successfully applied to a variety of application areas, including, for example, gene discovery, financial forecasting, and credit card fraud detection. This introductory course will study both the theoretical properties of machine learning algorithms and their practical applications. Students will have an opportunity to experiment with machine learning techniques and apply them to a selected problem in the context of term projects. Prerequisite: (CSCI101 or CSCI102 or CSCI128) and (MATH201 or MATH334) and MATH332.
Course Learning Outcomes

- 1. Understand the basic ideas of supervised learning, unsupervised learning and reinforcement learning, as well as their applications to real-world problems.
- 2. Use the linear models for regression and classification and write programs to implement these models using off-the-shelf packages.
- 3. Understand the kernel methods to deal with nonlinear problems and use support vector machines and neural networks to solve real-world problems.
- 4. Understand unsupervised learning and solve clustering and dimensionality reduction problems.
- 5. Understand reinforcement learning and its applications in robotics.

CSCI471. COMPUTER NETWORKS I. 3.0 Semester Hrs.
This introduction to computer networks covers the fundamentals of computer communications, using TCP/IP standardized protocols as the main case study. The application layer and transport layer of communication protocols will be covered in depth. Detailed topics include application layer protocols (HTTP, FTP, SMTP, and DNS), transport layer protocols (reliable data transfer, connection management, and congestion control), network layer protocols, and link layer protocols. In addition, students will program client/server network applications. Prerequisite: (CSCI220 or CSCI262) AND (CSCI210 or CSCI274).
Course Learning Outcomes

- using TCP/IP standardized protocols

CSCI473. ROBOT PROGRAMMING AND PERCEPTION. 3.0 Semester Hrs.
Equivalent with CSCI573,
In this class students will learn the basics of integrated robot system programming and the design and use of algorithms for robot perception. Students will learn how to use the ROS robot middleware for the design of robot systems for perceiving and navigating the world; develop reinforcement learning based models for perception-informed autonomous navigation; and develop computational models for 3D robot perception and perceptual representation of human data. Prerequisite: (CSCI220 or CSCI262),and,(MATH201 or MATH334).
Course Learning Outcomes

- 1. Explain the basic concepts in human-centered robotics
- 2. Model and analyze human behaviors for human-robot interaction applications
- 3. Recognize the cutting-edge human-centered robotics research and applications
- 4. Apply the learned knowledge to other fields

CSCI474. INTRODUCTION TO CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with MATH474,
This course is primarily oriented towards the mathematical aspects of cryptography, but is also closely related to practical and theoretical issues of computer security. The course provides mathematical background required for cryptography, including relevant aspects of number theory and mathematical statistics. The following aspects of cryptography will be covered: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Many practical approaches and most commonly used techniques will be considered and illustrated with real-life examples. Prerequisite: CSCI220 or CSCI262, CSCI358, MATH334 or MATH335 or MATH201.
Course Learning Outcomes

- Unchanged

CSCI475. INFORMATION SECURITY AND PRIVACY. 3.0 Semester Hrs.
Information Security and Privacy provides a hands-on introduction to the principles and best practices in information and computer security. Lecture topics will include basic components of information security including threat assessment and mitigation, policy development, forensics investigation, and the legal and political dimensions of information security. Completion of CSCI274 recommended. Prerequisite: (CSCI220 or CSCI262) and (CSCI 341) and (CSCI 210 or CSCI274).
Course Learning Outcomes

- unchanged

CSCI477. ELEMENTS OF GAMES AND GAME DEVELOPMENT. 3.0 Semester Hrs.
This course provides an overview of computer and video game development along with practical game projects designed to introduce the student to the computer entertainment industry. Topics will include the nature of games, the game player, game play, game design, game mechanics, story and character, game worlds, interface and the game development process. Students will be required to develop code both in C++ and with the use of a game engine. Prerequisite: CSCI220 or CSCI262.
Course Learning Outcomes

- By the end of this course, students will be able to: 1. Define the process of game software design and development from start to finish. 2. Develop a game design document and project plan to be utilized in the development and implementation of a game. 3. Develop a working game product using an existing game engine. 4. Write game programming code and scripting. 5. Identify the core types of AI behavior and their uses, such as pathfinding, fuzzy logic, cooperative behavior, decision trees, neural nets, adaptive and heuristics 6. Discuss the importance of story, character, actions and rewards as part of a successful game design. 7. Implement story, character, gameplay, challenges and mechanics in the design of a game.

CSCI478. INTRODUCTION TO BIOINFORMATICS. 3.0 Semester Hrs.
Bioinformatics is the theory, application and development of computing tools to solve problems and create hypotheses in all areas of biological sciences, which has contributed to advances in biology by providing tools that handle datasets too large and/or complex for manual analysis. This course focuses on an introduction to computational analysis of genetic variation and computational interdisciplinary research in genetics. The topics of this course include introduction to genetics, identification of genes involved in disease, inferring human population history, technologies for obtaining genetic information, and genetic sequencing, with an emphasis on formulating interdisciplinary problems as computational problems and then solving those problems using computational techniques from statistics and computer science. Prerequisite: CSCI101 or CSCI102 CSCI128.
Course Learning Outcomes

- 1. knowledge and awareness of the basic principles and concepts of biology, computer science and mathematics;
- 2. existing software to effectively extract information from large databases and to use this information in computer modeling;
- 3. problem-solving skills, including the ability to develop new algorithms and analysis methods;
- 4. an understanding of the intersection of life and information sciences, the core of shared concepts, language and;
- 5. skills the ability to speak the language of structure-function relationships, information theory, gene expression, and database queries.

CSCI480. COMPUTER SCIENCE HONORS THESIS. 3.0 Semester Hrs.
Prerequisite: CSCI306. 3 hours research; 3 semester hours. Repeatable for credit up to 6 semester hours.
Course Learning Outcomes

- TBA

CSCI490. PROGRAMMING CHALLENGES III. 1.0 Semester Hr.
This course is the third of three courses in the Programming Challenges sequence which covers problem solving patterns and paradigms found in technical interviews and programming competitions. The students will learn more advanced dynamic programming, graph theory, and algorithms while focusing on algorithmic complexity to solve problems in a finite amount of time. Prerequisite: CSCI390. Co-requisite: CSCI406.
Course Learning Outcomes

- Solve common programming problems and identify underlying patterns
- Argue and prove correctness of solution
- Determine and argue space and time complexity of solutions
- Combine common algorithms to solve problems
- Improve skills in technical interviews and programming competitions

CSCI498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Professor and Department Head

Iris Bahar

Professors

Qi Han

Dinesh Mehta

Hua Wang

Associate Professors

Neil Dantam

Bo Wu

Thomas Williams

Dejun Yang

Chuan Yue

Assistant Professors

Mehmet Belviranli

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Kaveh Fathian

Gabriel Fierro

C. Estelle Smith

Kelsey Fulton

Guannan Liu

Teaching Professors

Tolga Can

Jeffrey Paone

Wendy Fisher

Christopher Painter-Wakefield

Teaching Associate Professors

Keith Hellman

Phillip Romig III

Kathleen Kelly

Teaching Assistant Professors

Robert Thompson

Zibo Wang

Professors of Practice

Christine Liebe

Emeriti Professors

Tracy Camp , Emeritus Professor

William Hoff, Emeritus Associate Professor

Cyndi Rader, Emeritus Teaching Professor

Economics and Business

Degrees Offered:

- Bachelor of Science in Business Engineering and Management Science

Program Description

The economy is becoming increasingly global and dependent on advanced technology. In such a world, private companies and public organizations need leaders and managers who understand economics and business, as well as science and technology.

Programs in the Department of Economics and Business are designed to bridge the gap that often exists between economists and managers, on the one hand, and engineers and scientists, on the other. All Mines undergraduate students are introduced to economic principles in a required course, and many pursue additional coursework in minor programs or elective courses. The courses introduce undergraduate students to economic and business principles so that they will understand the economic and business environments, both national and global, in which they will work and live.

The Department of Economics and Business offers a Bachelor of Science in Business Engineering and Technology Management (BEMS). This degree develops graduates with applied quantitative skills that they can apply to data-driven business decisions. The BEMS degree lies at the intersection of technical skills and business training and enables students to develop leadership skills and passion that are needed in today's rapidly changing, technology-focused business world.

Bachelor of Science in BUSINESS ENGINEERING AND MANAGEMENT SCIENCE

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile, the Department of Economics and Business has established the following program educational objectives for the BS in Business Engineering and Management Science:

Upon completion of the Business Engineering and Management Science degree, students will be able to:

1. Identify, access, validate, and visualize relevant data to inform business decisions.
2. Demonstrate proficiency with deterministic and stochastic analytical tools.
3. Demonstrate mastery of basic business principles.
4. Build models and apply quantitative tools to inform decisions about business strategy and operations.
5. Communicate effectively in a professional context in a variety of formats.
6. Identify and propose solutions to ethical issues in business decision-making.
7. Demonstrate expertise in their track areas of choice.

Curriculum

The BS in Business Engineering and Management Science develops graduates with applied quantitative skills that Mines is known for including data science, data analytics, and operations research. This degree lies at the intersection of technical skills and business training and enables students to develop leadership skills and passion that are needed in today's rapidly changing, technology-focused business world.

The Business Engineering and Management Science degree provides comprehensive training in two core areas: Data Analytics and Business Principles. The Data Analytics core includes courses in data science, data visualization, predictive modeling and optimization modeling. The Business Principles core includes accounting, finance, marketing, communications, and management. In addition to these core courses, students specialize in tracks that allow them to deepen their knowledge of specific application areas. Students choose two three-course tracks from a selection of Business Analytics, Financial Economics, Artificial Intelligence and Machine Learning, and Technology Management.

Degree Requirements in Business Engineering and Management Science

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
PHGN100	PHYSICS I - MECHANICS			4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
EBGN201	PRINCIPLES OF ECONOMICS			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				15.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
HASS200	GLOBAL STUDIES			3.0
EBGN305	SURVEY OF ACCOUNTING			3.0
EBGN307	BUSINESS COMMUNICATIONS			3.0
				16.0

Spring		lec	lab	sem.hrs
ELECTIVE	CAS Mid-Level Restricted Elective			3.0
CSCI303	INTRODUCTION TO DATA SCIENCE			3.0
EBGN280	INTRODUCTION TO BUSINESS ANALYTICS			3.0
EBGN345	PRINCIPLES OF CORPORATE FINANCE			3.0
FREE	Free Elective			3.0
S&W	SUCCESS AND WELLNESS			1.0
				16.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
EBGN308	PRINCIPLES OF MARKETING			3.0
EBGN309	FUNDAMENTALS OF MANAGEMENT			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
EBGN381	PREDICTIVE BUSINESS ANALYTICS			3.0
FREE	Free Elective			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
EBGN303	ECONOMETRICS			3.0
EBGN382	PRESCRIPTIVE BUSINESS ANALYTICS			3.0
EBGN453	PROJECT MANAGEMENT			3.0
TRACK 1 TECHNICAL ELECTIVE #1				3.0
TRACK 2 TECHNICAL ELECTIVE #1				3.0
				15.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
EBGN490	BUSINESS ANALYTICS CAPSTONE			3.0
TRACK1 TECHNICAL ELECTIVE #2				3.0
TRACK 2 TECHNICAL ELECTIVE #2				3.0
ELECTIVE	CAS Mid-Level Restricted Elective			3.0
FREE	Free Elective			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
EBGN485	BUSINESS STRATEGY			3.0
TRACK 1 TECHNICAL ELECTIVE #3				3.0
TRACK 2 TECHNICAL ELECTIVE #3				3.0
ELECTIVE	CAS 400-Level Restricted Elective			3.0
FREE	Free Elective			3.0
				15.0

Total Semester Hrs: 122.0

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Minor Program in Economics

The minor in Economics requires that students complete six courses from the Division of Economics and Business, for a total of 18 credits. Minors are required to take Principles of Economics (EBGN201) and either Intermediate Microeconomics (EBGN301) or Intermediate Macroeconomics (EBGN302). Students must complete four additional EBGN courses. Up to 9 of the 18 hours required for the Economics minor may be used for other degree requirements including Culture and Society (CAS) electives. At least 9 of the hours required for the Economics minor must not be used for any part of the degree other than Free Electives.

Program Requirements:

EBGN201	PRINCIPLES OF ECONOMICS	3.0
EBGN301	INTERMEDIATE MICROECONOMICS	3.0
or EBGN302	INTERMEDIATE MACROECONOMICS	
EBGN	Economics Electives	12.0
Total Semester Hrs		**18.0**

Minor in Business and Entrepreneurship

The Minor in Business and Entrepreneurship provides the opportunity for students to gain skills and knowledge in business and entrepreneurship. The minor requires that students complete six business courses for a total of 18 credits. Requirements as follows:

Required		
EBGN321	ENGINEERING ECONOMICS	3.0
EBGN360	INTRODUCTION TO ENTREPRENEURSHIP	3.0
Select 4 of the following:		
EBGN201	PRINCIPLES OF ECONOMICS	3.0
EBGN280	INTRODUCTION TO BUSINESS ANALYTICS	3.0
EBGN305	SURVEY OF ACCOUNTING	3.0
EBGN307	BUSINESS COMMUNICATIONS	3.0
EBGN308	PRINCIPLES OF MARKETING	3.0
EBGN309	FUNDAMENTALS OF MANAGEMENT	3.0
EBGN315	THE ECONOMICS OF STRATEGY	3.0
EBGN345	PRINCIPLES OF CORPORATE FINANCE	3.0
EBGN346	INTRODUCTION TO INVESTMENTS	3.0
EBGN351	INTRODUCTION TO DECISION SCIENCE	3.0
EBGN453	PROJECT MANAGEMENT	3.0

At least 9 of the credits required for the Business and Entrepreneurship minor must not be used for any part of the degree other than Free Electives.

Area of Special Interest in Economics

The area of special interest in Economics requires that students complete Principles of Economics (EBGN201) and three other EBGN courses for a total of 12 credits. Except for Principles of Economics (EBGN201), EBGN courses taken to complete the ASI in Economics must not be used for any part of the degree other than Free Electives.

EBGN201	PRINCIPLES OF ECONOMICS	3.0
EBGNXXX	Economics Electives	9.0
Total Semester Hrs		**12.0**

Area of Special Interest in Entrepreneurship

The objective of the Area of Special Interest in Entrepreneurship is to supplement an engineering or applied science education with tools and processes to recognize and evaluate entrepreneurial opportunities. These tools include financial forecasting, business models and the interrelationships of business functions including accounting, marketing, finance, human resources, and operations. The processes include developing feasibility studies and business plans.

The area of Special Interest in Entrepreneurship requires that students complete Principles of Economics (EBGN201), Introduction to Entrepreneurship (EBGN360), Business Model Development (EBGN460), and one additional business course for a total of 12 credits.

EBGN201	PRINCIPLES OF ECONOMICS	3.0
EBGN360	INTRODUCTION TO ENTREPRENEURSHIP	3.0
EBGN460	BUSINESS MODEL DEVELOPMENT	3.0
Select 1 of the following:		
EBGN304	PERSONAL FINANCE	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
EBGN345	PRINCIPLES OF CORPORATE FINANCE	3.0
EBGN346	INTRODUCTION TO INVESTMENTS	3.0
EBGN425	BUSINESS ANALYTICS	3.0
EBGN485	BUSINESS STRATEGY	3.0

Courses

EBGN198. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN199. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN201. PRINCIPLES OF ECONOMICS. 3.0 Semester Hrs.

(I,II,S) Introduction to microeconomics and macroeconomics. This course focuses on applying the economic way of thinking and basic tools of economic analysis. Economic effects of public policies. Analysis of markets for goods, services and resources. Tools of cost-benefit analysis. Measures of overall economic activity. Determinants of economic growth. Monetary and fiscal policy. Prerequisites: None. 3 hours lecture; 3 semester hours.

EBGN230. INTRODUCTION TO BUSINESS. 3.0 Semester Hrs.

An introduction to everything business. In this class, you will explore why businesses are formed, what gives them a competitive advantage in the market, and how businesses report information to the public. You will also learn best practices for individual behavior and success when operating in a business environment, including what makes for a good business presentation, leading and communicating with teams, and project decision analysis. Being business smart is the foundation of every career path moving forward.

EBGN280. INTRODUCTION TO BUSINESS ANALYTICS. 3.0 Semester Hrs.

Business analytics implements a data-driven approach to the business world, leveraging statistics and data modeling to generate new business insights. In this introductory course, students will learn how to manage, visualize, and analyze data for business decision making. Students will use a variety of statistical methods, visualization tools, and data cleaning techniques to generate business insights from large data sets. Prerequisite: MATH201. Co-requisite: CSCI303.

Course Learning Outcomes

EBGN298. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN301. INTERMEDIATE MICROECONOMICS. 3.0 Semester Hrs.

Equivalent with EBGN411,

This course introduces the theoretical and analytical foundations of microeconomics and applies these models to the decisions and interactions of consumers, producers and governments. Develops and applies models of consumer choice and production with a focus on general equilibrium results for competitive markets. Examines the effects of market power and market failures on prices, allocation of resources and social welfare. Prerequisite: EBGN201 and MATH213.

EBGN302. INTERMEDIATE MACROECONOMICS. 3.0 Semester Hrs.

Equivalent with EBGN412,

Intermediate macroeconomics provides a foundation for analyzing both short-run and long-run economic performance across countries and over time. The course discusses macroeconomic data analysis (including national income and balance of payments accounting), economic fluctuations and the potentially stabilizing roles of monetary, fiscal and exchange rates policies, the role of expectations and intertemporal considerations, and the determinants of long-run growth. The effects of external and internal shocks (such as oil price shocks, resource booms and busts) are analyzed. Prerequisite: EBGN201 and MATH213.

EBGN303. ECONOMETRICS. 3.0 Semester Hrs.

Equivalent with EBGN390,

Introduction to econometrics, including ordinary least-squares and single- equation models; two-stage least-squares and multiple-equation models; specification error, serial correlation, heteroskedasticity, and other problems; distributive-lag models and other extensions, hypothesis testing and forecasting applications. Prerequisite: EBGN201 and MATH201.

EBGN304. PERSONAL FINANCE. 3.0 Semester Hrs.

The management of household and personal finances. Overview of financial concepts with special emphasis on their application to issues faced by individuals and households: budget management, taxes, savings, housing and other major acquisitions, borrowing, insurance, investments, meeting retirement goals, and estate planning. Survey of principles and techniques for the management of a household's assets and liabilities. Study of financial institutions and their relationship to households, along with a discussion of financial instruments commonly held by individuals and families.

EBGN305. SURVEY OF ACCOUNTING. 3.0 Semester Hrs.
An introduction to financial and managerial accounting topics of importance to managers and users of financial information. Topics include the origin, connection and purpose of financial statements, financial ratio computation and analysis, cash flow analysis for planning and decision making, inventory methods and cost accounting, fixed asset accounting, and fair value accounting. The course will focus on the use of accounting information for managerial decision making as well as the implications of business decisions on financial outcomes.

EBGN306. MANAGERIAL ACCOUNTING. 3.0 Semester Hrs.
Introduction to cost concepts and principles of management accounting including cost accounting. The course focuses on activities that create value for customers and owners of a company and demonstrates how to generate cost-accounting information to be used in management decision making. Prerequisite: EBGN201, EBGN305.

EBGN307. BUSINESS COMMUNICATIONS. 3.0 Semester Hrs.
Communication is one of the most vital skills in today's professional world, and effectiveness in communicating ideas, feelings, instructions, and thoughts are vital to both personal and professional success. Business Communications is designed to introduce you to skills and practices that will enable you to be an effective communicator for yourself, your business, and your clients and stakeholders. The course focuses on approaches for planning, creating, and transmitting business information within a variety of business situations found in the global marketplace. The course will focus on written, oral, and digital communication.
Course Learning Outcomes

- Analyze communication situations and audiences to make choices about the most effective and efficient way to communicate and deliver messages
- Conduct research that includes the use of print and electronic library resources and the Internet; use the results of the research to complete written and oral reports
- Conduct research that includes the use of print and electronic library resources and the Internet; use the results of the research to complete written and oral reports
- Deliver effective business presentations in contexts that may require either extemporaneous or impromptu oral presentations
- Provide feedback, accept feedback, and use feedback to improve communication skills
- Write business documents that are grammatically correct and use appropriate business style
- Develop effective interpersonal communication skills
- Develop skills in international and cross-cultural business communication and awareness of challenges required for successful communication in global organizations
- Use communication technology appropriately and effectively

EBGN308. PRINCIPLES OF MARKETING. 3.0 Semester Hrs.
Principles of Marketing will introduce students to the concepts, analyses, and activities that comprise marketing management and to provide practice in assessing and solving marketing problems. Marketing involves identifying customer needs, satisfying those needs through the right products and services, assuring availability to customers through the best distribution channels, using promotional activities in ways that motivate purchases as effectively as possible, and choosing a suitable price to boost firm profitability while maintaining customer satisfaction. These decisions of product, distribution, promotion, and price, together with a rigorous analysis of the customers, competitors, and the overall business environment serve as the foundations for sound marketing management.
Course Learning Outcomes

- Define marketing and outline the steps in the marketing process
- Explain the importance of understanding consumers and the marketplace, and identify the core marketplace concepts
- Identify the key elements of a customer-driven marketing strategy and discuss the marketing management orientations that guide market strategy
- Analyze qualitative and quantitative consumer data for use in determining appropriate marketing techniques that align with an organization's strategic focus, culture, and current business procedures
- Recommend product, price, promotional, and distribution strategies for a pre-defined target market through organizational marketing plans
- Maximize internal and external opportunities through the integration of marketing concepts, theories, and models
- Develop effective marketing strategies that address commercial, legal, and cultural aspects in global business environments
- Analyze marketing practices for compliance with legal systems, regulatory standards, and ethical practices

EBGN309. FUNDAMENTALS OF MANAGEMENT. 3.0 Semester Hrs.
This course provides a survey of fundamental principles of management and their application to the operations of a complex, modern organization. Topics covered include managerial functions (planning, organizing, leading, and controlling) as well as organizational behavior, human resources, and operations management.

EBGN310. ENVIRONMENTAL AND RESOURCE ECONOMICS. 3.0 Semester Hrs.
Application of microeconomic theory to topics in environmental and resource economics. Topics include analysis of pollution control, benefit/cost analysis in decision-making and the associated problems of measuring benefits and costs, non-renewable resource extraction, measures of resource scarcity, renewable resource management, environmental justice, sustainability, and the analysis of environmental regulations and resource policies. 3 hours lecture; 3 semester hours. Prerequisite: EBGN201.

EBGN315. THE ECONOMICS OF STRATEGY. 3.0 Semester Hrs.
An introduction to game theory and industrial organization (IO) principles at a practical and applied level. Topics include economies of scale and scope, the economics of the make-versus-buy decision, market structure and entry, dynamic pricing rivalry, strategic positioning, and the economics of organizational design. Prerequisite: EBGN201.
Course Learning Outcomes

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EBGN320. ECONOMICS AND TECHNOLOGY. 3.0 Semester Hrs.
The theoretical, empirical and policy aspects of the economics of technology and technological change. Topics include the economics of research and development, inventions and patenting, the Internet, e-commerce, and incentives for efficient implementation of technology. 3 hours lecture; 3 semester hours. Prerequisite: EBGN201.

EBGN321. ENGINEERING ECONOMICS. 3.0 Semester Hrs.
Equivalent with CHEN421,

Time value of money concepts of present worth, future worth, annual worth, rate of return and break-even analysis applied to after-tax economic analysis of mineral, petroleum and general investments. Related topics on proper handling of (1) inflation and escalation, (2) leverage (borrowed money), (3) risk adjustment of analysis using expected value concepts, (4) mutually exclusive alternative analysis and service producing alternatives.

EBGN330. ENERGY ECONOMICS. 3.0 Semester Hrs.
Equivalent with ENGY330,
Study of economic theories of optimal resource extraction, market power, market failure, regulation, deregulation, technological change and resource scarcity. Economic tools used to analyze OPEC, energy mergers, natural gas price controls and deregulation, electric utility restructuring, energy taxes, environmental impacts of energy use, government R&D programs, and other energy topics. Prerequisite: EBGN201.

EBGN340. ENERGY AND ENVIRONMENTAL POLICY. 3.0 Semester Hrs.
This course considers the intersection of energy and environmental policy from an economic perspective. Policy issues addressed include climate change, renewable resources, externalities of energy use, transportation, and economic development and sustainability. Prerequisites: EBGN201. 3 hours lecture; 3 semester hours.

EBGN345. PRINCIPLES OF CORPORATE FINANCE. 3.0 Semester Hrs.
Introduction to corporate finance, financial management, and financial markets. Time value of money and discounted cash flow valuation, risk and returns, interest rates, bond and stock valuation, capital budgeting and financing decisions. Introduction to financial engineering and financial risk management, derivatives, and hedging with derivatives. 3 hours lecture; 3 semester hours. Prerequisite: EBGN305.

EBGN346. INTRODUCTION TO INVESTMENTS. 3.0 Semester Hrs.
This course is an introduction to the principles of investment in competitive financial markets. The course will provide an overview to: 1) the structure of capital markets, 2) theories and practice of portfolio construction and management, 3) asset pricing theories used to analyze securities, 4) equity and debt securities, and 4) derivative instruments. 3 hours lecture; 3 semester hours. Prerequisites: EBGN305.
Course Learning Outcomes

- Identify and describe a wide variety of financial assets.
- Discuss securities makrets and how they operate.
- Determine the intrnsic value of stocks and bonds.
- Determine the efficient diversification of a portfolio.
- Calculate the value of options.
- Apply investment theory to real world problems.

EBGN351. INTRODUCTION TO DECISION SCIENCE. 3.0 Semester Hrs.
This course focuses on how to unwind complex situations to gain clarity, model uncertainty, and enable confident decision making. Students will learn how to frame the problem correctly, ensure clarity around the objectives, develop creative alternative strategies, and qualitatively or quantitatively evaluate those alternatives. Several tools for accomplishing these goals will be introduced. Topics will include decision trees, common psychological biases and traps, scenario analysis, game theory, modeling techniques, and subject-matter-expert interviews. Students will learn to analyze and present model outputs and how to avoid common pitfalls.
Course Learning Outcomes

EBGN360. INTRODUCTION TO ENTREPRENEURSHIP. 3.0 Semester Hrs.
This course introduces students to the entrepreneurial process, focusing on the concepts, practices, and tools of the entrepreneurial world. This will be accomplished through a combination of readings, cases, speakers, and projects designed to convey the unique environment of entrepreneurship and new ventures. The mastery of concepts covered in this course will lead to an initial evaluation of new venture ideas. In this course students will interact with entrepreneurs, participate in class discussion, and be active participants in the teaching/learning process. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- no change

EBGN381. PREDICTIVE BUSINESS ANALYTICS. 3.0 Semester Hrs.
Predictive analytics employs mathematical modeling techniques, utilizing known data to generate predictions about unknown events. This course offers an introduction to predictive analytics. In this course, students will learn the core concepts of supervised and unsupervised learning approaches. The course also addresses performance metrics for evaluating the prediction models and introduces ensemble modeling to enhance the precision and robustness of predictive models.
Course Learning Outcomes

EBGN382. PRESCRIPTIVE BUSINESS ANALYTICS. 3.0 Semester Hrs.
Prescriptive analytics strives to identify the best operational, tactical, and strategic decisions for organizations. In this course, students will learn the art of model building and will use linear, integer, and mixed-integer programming for a variety of business applications. Additionally, the course will provide an overview of specially structured models and model enhancement techniques. Prerequisite: EBGN280.
Course Learning Outcomes

EBGN398. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN401. ADVANCED TOPICS IN ECONOMICS. 3.0 Semester Hrs.
Application of economic theory to microeconomic and macroeconomic problems. This course will involve both theoretical and empirical modeling. Specific topics will vary by semester depending on faculty and student interest. Topics may include general equilibrium modeling, computational economics, game theory, the economics of information, intertemporal allocations, economic growth, microfoundations of macroeconomic models and policy simulation. 3 hours lecture; 3 semester hours. Prerequisites: EBGN301, EBGN302 and EBGN303.

EBGN403. ECONOMICS CAPSTONE. 1-4 Semester Hr.
Equivalent with EBGN402,
This is the capstone course for the economics major. Students will apply the tools they learned throughout the program to (1) conduct original economics research or (2) conduct an economic analysis for a client. In addition to the project, the capstone course will provide students

opportunities to interact with practitioners of economics and business as well as prepare a career plan. Prerequisite: EBGN301, EBGN302, EBGN303.

EBGN409. MATHEMATICAL ECONOMICS. 3.0 Semester Hrs.
Application of mathematical tools to economic problems. Coverage of mathematics needed to read published economic literature and to do graduate study in economics. Topics from differential and integral calculus, matrix algebra, differential equations, and dynamic programming. Applications are taken from mineral, energy, and environmental issues, requiring both analytical and computer solutions using programs such as GAMS and MATHEMATICA. Prerequisite: MATH213, EBGN301, EBGN302.

EBGN425. BUSINESS ANALYTICS. 3.0 Semester Hrs.
With the increasing availability of large volumes of raw business data, the process of converting it into meaningful insights has become critical for organizations to stay competitive. Driven by massive volumes of business data, business analytics has become instrumental in unveiling such managerial practices which guide the decision making process in companies at every operational stage. This course includes various descriptive, predictive and prescriptive business analytics strategies. It provides fundamental skills using quantitative tools to organize, process, and critically interpret business data, as well as key concepts in quantitative decision making to model and solve real-world problems. Prerequisite: EBGN201, MATH112.
Course Learning Outcomes

- How managers handle their data
- Different strategies and the use of technology in analyzing the data
- Quantitative decision making tools used to model and solve real-world problems
- Critical thinking skills used to interpret and learn from data, and derive meaningful insights

EBGN430. ADVANCED ENERGY ECONOMICS. 3.0 Semester Hrs.
(WI) Application of economic models to understand markets for oil, gas, coal, electricity, and renewable energy resources. Models, modeling techniques and applications include market structure, energy efficiency, demand-side management, energy policy and regulation. The emphasis in the course is on the development of appropriate models and their application to current issues in energy markets. Prerequisites: EBGN301, EBGN330. 3 hours lecture; 3 semester hours.

EBGN434. PROPERTY RIGHTS AND NATURAL RESOURCES. 3.0 Semester Hrs.
When choosing how to allocate our scarce resources, institutions serve as constraints at any given time. Over time, these institutions form and evolve when it appears profitable to do so. This course focuses on the North American story of resource use and draws on economics, law, and history to understand those processes and their implications. The course will provide a framework to understand why certain institutions were adopted and how they now shape our economic decisions today. Prerequisite: EBGN201.
Course Learning Outcomes

- Distinguish between legal and economic rights
- Understand how the distribution of economic rights impacts economic decisions
- Understand the impetus and frictions of changing economic property rights
- Be able to apply the property right theory to any example
- Have a better understanding of historical and current resource development in the American West

EBGN435. ECONOMICS OF WATER RESOURCES. 3.0 Semester Hrs.
This course seeks to develop the underlying economic problems of water use and how policy impacts the allocation of water in our economy. Water is a critical input for a number of sectors; from our basic sustenance to agriculture production, from industrial processes to ecological services, and from mineral extraction to energy production. Meanwhile, the supply of water is highly variable across space and through time while pollutants can further diminish the useable extent, making the policies to allocate and manage the resource central to understanding how the resource is utilized. The course will survey topics across sectors and water sources while applying economic theory and empirical/policy analysis. Prerequisite: EBGN409 or MATH213.
Course Learning Outcomes

- Apply economic modelling to water systems
- Analyze water policies empirically
- Review valuation techniques for water resources
- Conduct Cost-Benefit Analysis
- Comprehend how institutional structure effect development
- Use economic tools to asses water allocation and water pollution
- Analyze water use in specific sectors (ag, energy, mining, recreation, etc.)

EBGN437. REGIONAL ECONOMICS. 3.0 Semester Hrs.
(WI) Analysis of the spatial dimension of economies and economic decisions. Interregional capital and labor mobility. Location decisions of firms and households. Agglomeration economies. Models of regional economic growth. Measuring and forecasting economic impact and regional growth. Local and regional economic development policy. Urban and regional spatial structure. Emphasis on application of tools and techniques of regional analysis. Prerequisite: EBGN201.
Course Learning Outcomes

- no change

EBGN441. INTERNATIONAL ECONOMICS. 3.0 Semester Hrs.
Theories and determinants of international trade, including static and dynamic comparative advantage and the gains from trade. The history of arguments for and against free trade. The political economy of trade policy in both developing and developed countries. Prerequisite: EBGN301.

EBGN443. PUBLIC ECONOMICS. 3.0 Semester Hrs.
This course covers public-sector economics, including the fundamental institutions and relationships between the government and private decision makers. It covers the fundamental generalequilibrium welfare theorems and their interaction with government policy instruments that affect efficiency and distribution. Normative topics include an intensive study of the causes and consequences of, and policy prescriptions for, market failure due to public goods, or other problems associated with externalities and income distribution. Positive analysis focuses on policy formation in the context of political- economy and public choice theories. Prerequisite: EBGN201.

EBGN444. INNOV8X. 3.0 Semester Hrs.
Innovate X introduces concepts and tools to accelerate the design, validation and adoption of innovations in support of creative problem solving. Using an entrepreneurial mindset, we learn how to identify and frame problems that beneficiaries and stakeholders face. We attempt to design and test practical solutions to those problems in collaboration

with those who experience the problems. We apply beneficiary discovery, pretotyping, business model design (social, economic and environmental), constrained creativity, efficient experimentation, and rapid iteration. While resolving challenges involves technical solutions, an important aspect of this course is directly engaging beneficiaries and stakeholders in social contexts to develop solutions with strong impact potential. Innov8x is grounded in collaborative creativity theory at the intersection of organizational behavior (social psychology), design principles, entrepreneurship and innovation management.

Course Learning Outcomes

- Frame and translate complex ambiguous problems into actionable opportunities for innovation
- Conduct effective, objective and ongoing beneficiary discovery in efficient ways
- Combine tools and methods to quickly test assumptions and secure beneficiary acceptance
- Develop creative approaches to navigate real and perceived constraints
- Leverage mentor and stakeholder support through credible communication based on research
- Launch innovative solutions with the advocacy of beneficiaries and stakeholders
- Create value by solving complex problems that straddle technical and social domains

EBGN453. PROJECT MANAGEMENT. 3.0 Semester Hrs.

Project management has evolved into a business process broadly used in organizations to accomplish goals and objectives through teams. This course covers the essential principles of traditional project management consistent with professional certification requirements (the Project Management Institute's PMP certification) as well as an introduction to current agile project management methodologies. The traditional project management phases of project initiation, planning, execution, monitoring and control, and project closure are covered including related scheduling, estimating, risk assessment and other analytical tools. Students will gain experience using Microsoft Project. Organizational structure and culture issues are analyzed to understand how they can impact project management success, and the concepts of project portfolios and project programs are applied from the organizational perspective. Agile project management methodologies are introduced, including adaptive and iterative processes, scrum, lean and other Agile tools and techniques. By the end of the course, students will understand how traditional and agile project differ.

Course Learning Outcomes

- 1) Create a work breakdown structure for a proposed project
- 2) Define the five process groups of traditional project management as defined by the Project management Institute (PMI)
- 3) Investigate the role and responsibilities of a Project Manager and stakeholders
- 4) Compare the tools and techniques for small, medium and large projects.
- 5) Interpret your own leadership abilities and how to grow as a leader
- 6) Create a project statement of work document with schedule, and financial analysis
- 7) Formulate the project issues, scope changes, and the resulting risk profile changes for a project.
- 8) Perform a basic project risk assessment
- 9) Assess Agile project management and how it differs from traditional project management.
- 10) Recognize the golden rules of change management
- 11) Create a business case and financial justification for a large project.

EBGN455. LINEAR PROGRAMMING. 3.0 Semester Hrs.

This course addresses the formulation of linear programming models, examines linear programs in two dimensions, covers standard form and other basics essential to understanding the Simplex method, the Simplex method itself, duality theory, complementary slackness conditions, and sensitivity analysis. As time permits, multi-objective programming, an introduction to linear integer programming, and the interior point method are introduced. Applications of linear programming models discussed in this course include, but are not limited to, the areas of manufacturing, finance, energy, mining, transportation and logistics, and the military. Prerequisite: MATH332 or EBGN409.

EBGN459. SUPPLY CHAIN MANAGEMENT. 3.0 Semester Hrs.

As a quantitative managerial course, the course will explore how firms can better organize their operations so that they more effectively align their supply with the demand for their products and services. Supply Chain Management (SCM) is concerned with the efficient integration of suppliers, factories, warehouses and retail-stores (or other forms of distribution channels) so that products are provided to customers in the right quantity and at the right time. Topics include managing economies of scale for functional products, managing market- mediation costs for innovative products, make-to order versus make-to-stock systems, quick response strategies, risk pooling strategies, supply-chain contracts and revenue management. Additional "special topics" will also be introduced, such as reverse logistics issues in the supply-chain or contemporary operational and financial hedging strategies. Prerequisite: None.

EBGN460. BUSINESS MODEL DEVELOPMENT. 3.0 Semester Hrs.

This course leads students through the process of developing and validating a business model for an innovative product or service by a start-up or an established organization. The creation of a business model can be challenging, frustrating, fascinating and fulfilling. Building on skills learned in EBGN360, students explore ways to sustain and scale a promising new product or service in any context: commercial/for-profit, social/non-profit or government. It is an iterative process that involves uncovering beneficiary needs and leads to an in-depth understanding of how value is delivered, differentiated and captured. Students work in teams since new ventures are started by teams with complementary skills and a shared purpose. This is a demanding, hands-on course that integrates knowledge from entrepreneurship, business, economics and engineering classes. Students are expected to initiate and drive an intense beneficiary discovery process that involves reaching out to beneficiaries and engaging them outside class. Prerequisite: EBGN360. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- no change

EBGN461. STOCHASTIC MODELS IN MANAGEMENT SCIENCE. 3.0 Semester Hrs.

As a quantitative managerial course, the course is an introduction to the use of probability models for analyzing risks and economic decisions and doing performance analysis for dynamic systems. The difficulties of making decisions under uncertainty are familiar to everyone. We will learn models that help us quantitatively analyze uncertainty and how to use related software packages for managerial decision-making and to do optimization under uncertainty. Illustrative examples will be drawn from many fields including marketing, finance, production, logistics and distribution, energy and mining. The main focus of the course is to see methodologies that help to quantify the dynamic relationships of sequences of "random" events that evolve over time.

EBGN470. ENVIRONMENTAL ECONOMICS. 3.0 Semester Hrs.
(WI) This course considers the role of markets as they relate to the environment. Topics discussed include environmental policy and economic incentives, market and non-market approaches to pollution regulation, property rights and the environment, the use of benefit/cost analysis in environmental policy decisions, and methods for measuring environmental and nonmarket values. Prerequisite: EBGN301. 3 hours lecture; 3 semester hours.

EBGN474. INVENTING, PATENTING AND LICENSING. 3.0 Semester Hrs.
(S) (WI) This course provides an introduction to the legal framework of inventing and patenting and addresses practical issues facing inventors. The course examines patent law, inventing and patenting in the corporate environment, patent infringement and litigation, licensing, and the economic impact of patents. Methods and resources for market evaluation, searching prior art, documentation and disclosure of invention, and preparing patent applications are presented. Prerequisite: None. 3 hours lecture; 3 semester hours.

EBGN485. BUSINESS STRATEGY. 3.0 Semester Hrs.
Business strategy is focused on formulating and implementing the major goals of the firm in relation to changing competitive environmental conditions, firm resources, and individuals' motives and values. This course is about the issues and challenges of running a firm in a competitive environment from the perspective of a senior manager. The challenge for senior managers goes well beyond applying an appropriate formula to a problem because to date there are not any universal formulas for successful companies. Rather, senior managers must be able to identify that a problem exists and then to bring resolution, despite partial information. This course requires identifying, analyzing, and solving firm problems with original thinking and execution. A key instructional objective of this course is to help you develop a rigorous approach for addressing complex business problems. Prerequisites: EBGN308 or EBGN345.
Course Learning Outcomes

- Understand the fundamental concepts associated with Strategic Management, such as conducting analyses of the competitive environment a firm faces, assessing firm resources and potential sources of competitive advantages
- Be able to identify problems in a complex business scenario
- Understand what pieces of information are important in diagnosing a strategic challenge and to apply the correct tools in addressing that challenge
- Develop an understanding of how to design and implement firm level strategies that develop, exploit and sustain competitive advantage

EBGN490. ANALYTICS. 3.0 Semester Hrs.
The business analytics capstone course provides an opportunity for students to integrate and apply the skills and tools learned in previous business analytics courses to define, formulate, analyze, and recommend a solution for a significant, real-world business problem. Students will work as a team, and will draw on the breadth and depth of the curriculum to address an industry supplied problem.
Course Learning Outcomes

EBGN495. ECONOMIC FORECASTING. 3.0 Semester Hrs.
An introduction to the methods employed in business and econometric forecasting. Topics include time series modeling, Box- Jenkins models, vector autoregression, cointegration, exponential smoothing and seasonal adjustments. Covers data collection methods, graphing, model building, model interpretation, and presentation of results. Topics include demand and sales forecasting, the use of anticipations data, leading indicators and scenario analysis, business cycle forecasting, GNP, stock market prices and commodity market prices. Includes discussion of links between economic forecasting and government policy. Prerequisite: EBGN301, EBGN302, EBGN303.

EBGN496. PAYNE SCHOLARS PROGRAM. 1.0 Semester Hr.
The Payne Scholars program is a one-credit, independent study course that helps students perform research, collaborate across campus, and engage with a broad network of international experts on global policy challenges. Students are taught how to write academic papers on the important issues we are facing today, and once the students finish the course, the papers they write can be published as Payne Commentaries on our website. Payne Scholars will participate in the Payne Institutes guest lecture series, discuss developing policy trends and concerns, and write on the evolving public policy landscape. As a part of School of Mines, the Payne Institute for Public Policy is dedicated to fostering the essential relationship between technical knowledge and public policy. Mines graduates often go on to become corporate leaders and are responsible for many of the innovations and changes seen across industries. In much the same way, the research done at Mines has far reaching implications for many of the social, economic, and environmental challenges faced around the world.
Course Learning Outcomes

- Analyze policy issues using tools from a variety of relevant disciplines
- Write clear and concise academic and policy documents
- Translate technical information into digestible policy narratives
- Collaborate with industry professionals
- Apply appropriate research techniques
- Properly cite and format their work for different audiences and purposes

EBGN498. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 0.5-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Professor

Jared Carbone

Research Professor

Roderick G. Eggert

Associate Professors

Qiaohai (Joice) Hu

Ian Lange

Steven Smith

Assistant professors

Maxwell Brown

Ben Gilbert

Teaching Professors

Scott Houser, Department Head

Becky Lafrancois

Teaching Associate Professors

Crystal Dobratz

Sheron Lawson

Andrew Pederson

Jeremy Suiter

Professor of Practice

Thomas Brady

David Culbreth

Patrick Leach

Paul Zink

Professors Emeriti

Carol A. Dahl

John E. Tilton

Graham Davis

Franklin J. Stermole

Michael R. Walls

Engineering, Design, and Society

Program Description

The Department of Engineering, Design, and Society (EDS) engages in research, education, and outreach that inspires and empowers engineers and applied scientists to become innovative and impactful leaders. Our specialization is in socio-technical integration, design problem definition and solution, and interdisciplinary, real-world engineering design educational experiences. We seek to educate future leaders who will address the challenges of attaining a thriving, sustainable global society.

EDS is home to:

Bachelor of Science in Design Engineering: Design Engineering is an interdisciplinary engineering degree that focuses on the creation of innovative solutions to the challenging problems facing people, societies, and the world. Through a sequence of Integrated Design Studios that bridge first-year Cornerstone Design and senior-year Capstone Design, students become experts in design methods that deploy engineering principles to address human problems in real-world contexts. Design Engineering provides the flexibility for students to create specialized focus areas that suit their individual career and personal interests, and it ensures they gain practical engineering experience throughout their education at Mines.

Humanitarian Engineering: Mines' Humanitarian Engineering (HE) program is recognized internationally for its research, education, and outreach in socially responsible engineering. At the undergraduate level, HE includes two minors, Engineering for Community Development and Leadership in Social Responsibility, along with a range of electives courses open to all Mines students. At the graduate level, the interdisciplinary Humanitarian Engineering and Science program offers MS thesis and non-thesis degree options as well as a graduate certificate. HE enables Mines students to understand how engineering can contribute to co-creating just and sustainable solutions to the problems faced by communities globally.

Cornerstone Design: Cornerstone Design is a two-course sequence introducing Mines students to the engineering problem solving process. Cornerstone Design I (EDNS151), enrolled by all first-year Mines students, teaches open-ended problem solving, project management, professional communications, and teaming skills—all within a human-centered design framework. Cornerstone Design II (EDNS251 or a similar second-year course), enrolled by approximately half of Mines sophomore engineering students, applies and advances lessons from Cornerstone Design I by responding to real-world engineering challenges.

Capstone Design: Capstone Design entails a culminating two-semester senior design sequence for over half of Mines' engineering students, including those in the Design, Civil, Electrical, Environmental, and Mechanical Engineering programs. Capstone Design proram provides unique client-sponsored, hands-on, interdisciplinary engineering project experiences for participating students.

Programs

Design Engineering

The Bachelor of Science in **Design Engineering** offers an interdisciplinary, creative, and flexible program of study that complements Mines' signature strengths in engineering and applied science. Design Engineering integrates:

1) The inspiration and engagement of studio-based **design education** focusing on technology innovation; open-ended problem solving, and social impact

2) The insights and analytic perspectives of a **broad, liberal arts education**, which helps students focus attention on the right problems and the best overall solutions

3) Mines' signature strength in **engineering applications**, built upon the fundamentals of mathematics, science, and engineering analysis

The Design Engineering curriculum revolves around hands-on, project-based design studios every semester, culminating in Capstone Design. We offer a unique educational experience through our Integrative Design Studios, which bridge the technical, social, and creative potentials of engineering problem solving. Additionally, Design Engineering allows students to specialize in a focus area of their choice, enabling students to apply their design expertise and pursue depth of study in an area of personal interest. Focus areas span emerging technologies, the application of technology to underserved communities, and the creation of new technology-driven startups. Design Engineering program details are provided under the Major tab above.

Humanitarian Engineering

Humanitarian Engineering (HE) serves students with a passion for contributing to social and environmental problem solving. HE connects these students to Mines faculty who lead in applying engineering techniques to pressing social, environmental, and community challenges. Integrating engineering with social sciences and design, the HE program spans minors, Design Engineering focus areas, and elective courses where students learn how to work *with* the communities they serve to co-create solutions that promote justice, responsibility, and sustainability. HE serves students from any discipline and with diverse career goals spanning NGOs, government agencies and research groups, startup businesses, and established companies. Seminar-style courses offered by the Engineering, Design, and Society Department and the Humanities, Arts, and Social Sciences Department, along with selected technical electives offered by other academic units across campus, provide students a balance of breadth and depth in areas related to Humanitarian Engineering. HE program details are provided under the Minor tab above.

Engineering for Community Development

The HE Minor in Engineering for Community Development (ECD) is an evolution of the country's very first minor in Humanitarian Engineering created at Mines in 2003. Designed specifically for engineers and applied scientists who desire to serve communities, the ECD minor prepares students to become leaders in community development through engineering.

Graduates with the ECD minor can work at the U.S. Peace Corps (see Mines Peace Corps Prep Program), community service NGOs, international organizations, or a range of companies hosting projects related to community development. The knowledge and skills learned through the ECD minor prepares graduates for any engineering job involving community engagement, cross-cultural work environments, or human-centered design.

The ECD minor is designed to support any degree program on campus.

Leadership in Social Responsibility

The HE Minor in Leadership in Social Responsibility (LSR) is the country's first undergraduate minor in social responsibility designed specifically for engineers and applied scientists. The LSR minor prepares Mines students to become leaders in promoting shared social, environmental, and economic value for companies and their stakeholders.

Graduates of the LSR minor are sought by corporate employers that desire engineers who are prepared to factor public perception and community acceptance into the decisions they make and the technologies and processes they design. Graduates will also be prepared to take jobs that focus on corporate social responsibility, stakeholder engagement, and sustainability.

The LSR minor is designed to support any degree program on campus.

Humanitarian Engineering and Science (HES) Graduate Programs

The EDS Department also delivers the core curriculum of the inter-departmental Humanitarian Engineering and Science graduate programs. HES program details are in the Mines Catalog under Interdisciplinary Graduate Programs and are also summarized under the Humanitarian Engineering Masters tab above.

Cornerstone Design

Cornerstone Design immerses students in hands-on, open-ended problem-solving through iterative, project-based inquiry. Cornerstone Design combines engineering design, design thinking, and systems analysis to pursue open-ended problem scoping, definition, and articulation—all supported by direct stakeholder engagement and scholarly research. Students learn creative concept generation and selection techniques, solution validation and iteration, prototype development and testing, authoritative information gathering, and engineering analysis. Throughout these design experiences, students learn fundamental STEM analysis, a variety of design tools, and the professional communication skills necessary for academic and professional success.

In Cornerstone Design I (EDNS151), students work in teams on a semester-long design project, learning to communicate technical ideas and solutions visually, orally, in writing, and through prototype demonstrations. Cornerstone Design I introduces students to the human-centered design process, which includes exploration, ideation, solution concept development, and validation, while also ensuring solutions are viable, desirable, feasible, and sustainable.

Cornerstone Design II (EDNS251 and related courses) builds on the foundation of Cornerstone Design I by having student teams manage a client relationship and use commercial design software to model, predict, and analyze solution concepts. Students should check with their degree program to determine whether Cornerstone Design II is stipulated or permissible for satisfying program requirements.

Capstone Design

Capstone Design offers a one-of-a-kind, creative, multidisciplinary, team-based design experience for participating students in Design, Civil, Electrical, Enviornmental, and Mechanical Engineering. Capstone Design embraces the uniqueness of each disciplinary approach while enabling students to address real-world, interdisciplinary challenges. Capstone Design entails a two-semester, senior-year course sequence: Capstone Design I (EDNS491) and Capstone Design II (EDNS492).

Capstone Design addresses ABET accreditation guidelines for the engineering programs, particularly Criterion 3 Student Outcomes 2-5:

- An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- An ability to communicate effectively with a range of audiences.
- An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
- An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

The **Capstone Design Showcase** celebrates the engineering design achievements of participating students. This campus-wide celebration offers Capstone students an opportunity to present their real-world, client-driven design outcomes completed as part of their Capstone coursework.

The Bachelor of Science in Design Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission's General Criteria with no applicable program criteria.

Program Educational Objectives

The objectives of the Engineering, Design, & Society Bachelor of Science in Design Engineering program are to produce graduates who, within five years of graduation, will:

- Apply their creative interpretation of complex problems and propose novel solution concepts within unique social, technical, ethical and environmental constraints.
- Serve as innovators, bridging the gap between social, technical and creative design disciplinary teams, all while incorporating a high level of ethical standards, social consciousness and technical expertise.
- Seek to contribute to interdisciplinary endeavors and establish positions of leadership through service activities within their profession or community.
- Actively engage in lifelong learning, demonstrating continuous professional growth.

Student Learning Outcomes

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Bachelor of Science in Design Engineering

The Bachelor of Science in Design Engineering is a flexible, interdisciplinary program of study combining:

1. The strength of a Mines' technical degree with fundamentals coursework in mathematics, science, and engineering
2. An integrated educational experience spanning engineering, design, innovation, social sciences, and the humanities and
3. A Focus Area allowing for a depth of study in an area of personal or career interest, such as innovation and emerging technologies, sustainability and socially responsible applications of engineering, or an individualized focus area at the intersection of technology and society.

These three components are brought together via:

4. A unique set of six Integrative Design Studios, culminating in the two-semester Capstone Design Studio.

The Integrative Design Studios teach students how to respond to authentic, open-ended problems by integrating diverse skills, perspectives, and disciplinary approaches. They also provide a broad set of design competencies that are applicable to solving problems in any domain. Students work on a wide variety of hands-on projects, individually and in teams, mastering the capacity to move creatively from ill-structured problems to concrete, innovative, human-centered solutions. Through this journey, students also develop a diverse project portfolio, illustrating their unique skills and individual identity as a design engineer.

In parallel with the experiential design approach of the integrative design studios, students have great flexibility in selecting engineering fundamentals and electives courses from a wide variety of engineering disciplines. This flexibility allows students to prepare for their chosen Focus Area or to chart their own engineering, innovation, or design pathways.

The program also includes a design applications experience (EDNS392) for students to develop a critical understanding of how engineers analyze their design work in the social and technical realms of open-ended problem solving. This opportunity provides motivations for students to explore career options early. It also helps them better understand how their individual design expertise can contribute to a variety of engineering problems, organizational needs, and multidisciplinary teams. Together, the key components of the program promote a "design early, design often, design real" approach to engineering education.

Program Educational Outcomes

Within several years of completing the degree, graduates with a Bachelor of Science in Design Engineering will be engaged in progressively more responsible positions as:

<u>Innovators</u> who are comfortable taking risks and who are energized by the belief that engineers help make the world a better place by improving people's lives through technologies designed with and for people and the planet.

<u>Design Thinkers</u> who confidently approach engineering problems from a human and nature-centric perspective and identify multiple design solutions before converging on improvements and results that balance technical, economic, environmental, and societal goals.

<u>Impact Makers</u> who are much more than "just" engineers, with a broad perspective to responsibly envision, design, and implement new technologies that make a positive impact on people, organizations, the environment, and society.

Student Outcomes

Graduates of the program will have attained ABET Student Outcomes 1-7.

Curriculum

The Design Engineering degree program offers students a combination of courses that includes core mathematics, basic and advanced sciences, engineering fundamentals, and foundational studies in the social sciences and humanities throughout the freshman and sophomore years.

There is strong alignment of the initial course sequence between this degree program and other engineering degree programs at Mines, allowing smooth entry into the Bachelor of Science in Design Engineering degree program at any time during the first two years.

In the junior and senior years, students complete fundamental engineering courses across the breadth of traditional engineering disciplines and pursue advanced disciplinary studies through additional engineering electives, emphasizing engineering's breadth as well as commonalities among different engineering disciplines. Integrated with their technical studies, students learn about the many human dimensions of defining and solving problems using perspectives and approaches from the social sciences, humanities, and design, including the creative, social, cultural, political (including policy), economic, and business components critical for understanding the big challenges facing society and the environment today.

A central component of this degree program is the extensive application of technical and non-technical skillsets in response to real-world problems throughout the Integrative Design Studios. This approach increases and solidifies students' understanding of the content from their other courses. The Integrative Design Studio culminates in the Capstone Design Studio sequence, where students draw together the entirety of their educational experience to solve client-sponsored engineering problems in specific areas of student interest.

Bachelor of Science in Design Engineering: Degree Requirements

The curriculum comprises six groups of coursework and experiential learning for a total of 132 credits:

Freshman

Fall		**lec**	**lab**	**sem.hrs**
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
EDNS200	INTRODUCTION TO DESIGN ENGINEERING			3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
S&W	SUCCESS AND WELLNESS			1.0
HASS100	NATURE AND HUMAN VALUES			3.0
				15.0

Sophomore

Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS*			4.0
MATH201	INTRODUCTION TO STATISTICS, CBEN 110, CHGN 122, CHGN 125, CSCI 101, or GEGN 101*#			3.0
EDNS291	DESIGN UNLEASHED**			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective##			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				18.0

Spring		**lec**	**lab**	**sem.hrs**
MATH225	DIFFERENTIAL EQUATIONS			3.0
CEEN241	STATICS#			3.0
MEGN261	THERMODYNAMICS I, CHGN 209, or CBEN 210			3.0
EDNS292	DESIGN FOR A GLOBALIZED WORLD			3.0
ENGR	ENGINEERING ELECTIVE###			3.0
				15.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
MEGN212	INTRODUCTION TO SOLID MECHANICS, CEEN 311, or MTGN 202			3.0
EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER or 282#			3.0
ENGR	ENGINEERING ELECTIVE###			3.0
EDNS391	DESIGN & MODELING OF INTEGRATED SYSTEMS			3.0
FOCUS	FOCUS AREA####			3.0
				18.0

Spring		**lec**	**lab**	**sem.hrs**
ENGR	ENGINEERING ELECTIVE###			3.0
MEGN351	FLUID MECHANICS, CBEN 307, or CEEN 310			3.0
ENGR	ENGINEERING ELECTIVE###			3.0
EDNS392	DESIGN ENGINEERING APPLICATIONS			3.0

FOCUS	FOCUS AREA####			3.0
FREE	FREE ELECTIVE			3.0
				18.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
ENGR	ENGINEERING ELECTIVE###			3.0
EDNS491	CAPSTONE DESIGN I			3.0
FOCUS	FOCUS AREA####			3.0
FOCUS	FOCUS AREA####			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective##			3.0
FREE	FREE ELECTIVE			3.0
				18.0
Spring		**lec**	**lab**	**sem.hrs**
EDNS492	CAPSTONE DESIGN II			3.0
FOCUS	FOCUS AREA####			3.0
FOCUS	FOCUS AREA####			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective##			3.0
FREE	FREE ELECTIVE			3.0
				15.0

Total Semester Hrs: 132.0

* A minimum of 10 credits of Core Distributed Science courses are required. Students must take PHGN200 (PHYSICS II – ELECTROMAGNETISM AND OPTICS) and two of the common distributed science courses: CBEN110, CHGN122 or CHGN125, CSCI101, GEGN101, and MATH201. One of CSCI101 (INTRODUCTION TO COMPUTER SCIENCE) or MATH201 (PROBABILITY AND STATISTICS FOR ENGINEERS) must be taken from this list, and both can be taken depending on student preference.

*# Students have limited flexibility as to when to take two of their Core Distributed Science courses starting in their freshman year into early junior year, and should be decided in consultation with student's advisor to accommodate prerequisite requirements.

** MEGN200 does not substitute for EDNS291 DESIGN Unleashed credit in any other degree program at this time. Additionally, the EDNS292 sequence does not count toward MEGN200 credit for students transferring out of the DE program into Mechanical Engineering at this time.

\# ENGINEERING FUNDAMENTALS courses are: (1) one of the **thermodynamics** courses CHGN209 or CBEN210; (2) **statics** CEEN241; (3) one of the **circuits** courses EENG281 or EENG282; (4) one of the **materials** courses MTGN202, CEEN311, or MEGN212; and (5) one of the **fluid mechanics** courses CEEN310, or MEGN351. Prerequisites may apply.

\## Culture and Society (CAS) Restricted Elective courses, a minimum of 9 credit hours of upper level coursework, as described in the Core Curriculum section of the catalog. Focus Areas may list recommended courses to use for these electives.

\### ENGINEERING ELECTIVES are purposefully drawn from course offerings provided through other engineering programs. Details are provided in the following section. Some of the Focus Areas identify specific courses from the list of allowed engineering electives that must be taken to satisfy the requirements of the Focus Area. Those engineering elective courses are identified in the Focus Area description as being outside of the 18 credits allocated to Focus Area Coursework.

\#### Focus Area courses are a coherent set of required and suggested elective offerings around a particular topic. Details are given the Focus Area Requirements section below.

Bachelor of Science in Design Engineering: Engineering Coursework Requirements:

A minimum of 30 credits of Design Engineering Coursework (designated as ENGR in the Bachelor of Science in Design Engineering Degree Requirements listing above) are required (typically ten courses). 15 credits (typically five courses) are prescribed ENGINEERING FUNDAMENTALS courses as noted in footnote # above. The additional 15 credits are ENGINEERING ELECTIVES. The requirement of 30 credits of Engineering Coursework may include engineering courses taken as a part of a student's Focus Areas (Focus Areas may require specific engineering courses be taken – see footnote ### above). This Engineering Coursework requirement combined with specific engineering content in the six INTEGRATIVE DESIGN STUDIOs (allocating 11 credits of the 18 credits for the design studios) and the Capstone Senior Design sequence (EDNS491 and EDNS492) produces 47 credits of engineering course work for this degree program. Note that certain ENGINEERING FUNDAMENTALS may also be prescribed by a Focus Area in order to satisfy prerequisite requirements. Likewise, students are encouraged to select ENGINEERING ELECTIVES to reinforce and complement the courses in the student's chosen Focus Area. ENGINEERING ELECTIVES must be chosen from the list below, or select 400-level courses discussed with and approved by the student's advisor. Finally, note that students must have at least 9 credits at or above the 300-level with a common theme or subject area within the group of courses that make up the required 30 credits of ENGINEERING FUNDAMENTALS and ENGINEERING ELECTIVES to ensure a reasonable level of disciplinary depth in a single field of engineering. Furthermore, students must have at least 9 credits at or above the 400-level of ENGINEERING ELECTIVES plus the 6 credits of capstone senior design course and project work (EDNS491 and EDNS492).

The complexity of integrating various department curriculum, the potential for missing prerequisites, and the need to follow an expected course sequence requires that students develop a 2nd, 3rd and 4th year plan with their advisor during the first semester of their sophomore year course of study, and to collaboratively work with their advisor and Program Director for curricular assessment and approval prior to registration for every semester. The course plan is expected to be a dynamic roadmap for a student's particular degree curriculum.

The following engineering-content courses can be used to satisfy the 15-credit requirement for ENGINEERING ELECTIVES. Please be aware of course prerequisites, reviewed with the student's advisor. The below list includes approved coursework, but is not exhaustive. Students can seek approval from faculty advisor for a course not listed below.

Chemical Engineering		
CBEN308	HEAT TRANSFER	3.0
CBEN310	INTRODUCTION TO BIOMEDICAL ENGINEERING	3.0
CBEN312	UNIT OPERATIONS LABORATORY	3.0
CBEN313	UNIT OPERATIONS LABORATORY	3.0

CBEN314	CHEMICAL ENGINEERING HEAT AND MASS TRANSFER	4.0
CBEN315	INTRODUCTION TO ELECTROCHEMICAL ENGINEERING	3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY	1.0
CBEN360	BIOPROCESS ENGINEERING	3.0
CBEN365	INTRODUCTION TO CHEMICAL ENGINEERING PRACTICE	3.0
CBEN372	INTRODUCTION TO BIOENERGY	3.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS	3.0
CBEN401	PROCESS OPTIMIZATION	3.0
CBEN403	PROCESS DYNAMICS AND CONTROL	3.0
CBEN408	NATURAL GAS PROCESSING	3.0
CBEN409	PETROLEUM PROCESSES	3.0
CBEN415	POLYMER SCIENCE AND TECHNOLOGY	3.0
CBEN416	POLYMER ENGINEERING AND TECHNOLOGY	3.0
CBEN418	KINETICS AND REACTION ENGINEERING	3.0
CBEN420	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	3.0
CBEN422	CHEMICAL ENGINEERING FLOW ASSURANCE	3.0
CBEN426	ADVANCED FUNCTIONAL POROUS MATERIALS	3.0
CBEN430	TRANSPORT PHENOMENA	3.0
CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN435	INTERDISCIPLINARY MICROELECTRONICS	3.0
CBEN440	MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING	3.0
CBEN454	APPLIED BIOINFORMATICS	3.0
CBEN460	BIOCHEMICAL PROCESS ENGINEERING	3.0
CBEN461	BIOCHEMICAL PROCESS ENGINEERING LABORATORY	1.0
CBEN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
CBEN480	NATURAL GAS HYDRATES	3.0
Civil & Environmental Engineering		
CEEN301	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER	3.0
CEEN302	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: AIR AND WASTE MANAGEMENT	3.0
CEEN303	ENVIRONMENTAL ENGINEERING LABORATORY	3.0
CEEN312	SOIL MECHANICS	3.0
CEEN312L	SOIL MECHANICS LABORATORY	1.0
CEEN314	STRUCTURAL ANALYSIS	3.0
CEEN315	CIVIL AND ENVIRONMENTAL ENGINEERING TOOLS	1.0
CEEN330	ENGINEERING FIELD SESSION, ENVIRONMENTAL	3.0
CEEN331	ENGINEERING FIELD SESSION, CIVIL	3.0
CEEN350	CIVIL AND CONSTRUCTION ENGINEERING MATERIALS	3.0
CEEN360	INTRODUCTION TO CONSTRUCTION ENGINEERING	3.0
CEEN381	HYDROLOGY AND WATER RESOURCES ENGINEERING	3.0
CEEN401	LIFE CYCLE ASSESSMENT	3.0
CEEN405	NUMERICAL METHODS FOR ENGINEERS	3.0
CEEN406	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN410	ADVANCED SOIL MECHANICS	3.0
CEEN411	UNSATURATED SOIL MECHANICS	3.0
CEEN415	FOUNDATION ENGINEERING	3.0
CEEN419	RISK ASSESSMENT IN GEOTECHNICAL ENGINEERING	3.0
CEEN421	HIGHWAY AND TRAFFIC ENGINEERING	3.0
CEEN423	SURVEYING FOR ENGINEERS AND INFRASTRUCTURE DESIGN PRACTICES	3.0
CEEN425	CEMENTITIOUS MATERIALS FOR CONSTRUCTION	3.0
CEEN426	DURABILITY OF CONCRETE	3.0
CEEN430	ADVANCED STRUCTURAL ANALYSIS	3.0
CEEN433	MATRIX STRUCTURAL ANALYSIS	3.0
CEEN449	INTRODUCTION TO THE SEISMIC DESIGN OF STRUCTURES	3.0
CEEN442	DESIGN OF WOOD STRUCTURES	3.0
CEEN443	DESIGN OF STEEL STRUCTURES	3.0
CEEN445	DESIGN OF REINFORCED CONCRETE STRUCTURES	3.0
CEEN448	STRUCTURAL LOADS	3.0
CEEN460	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
CEEN461	FUNDAMENTALS OF ECOLOGY	3.0
CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES	3.0
CEEN472	ONSITE WATER RECLAMATION AND REUSE	3.0
CEEN473	HYDRAULIC PROBLEMS	3.0
CEEN475	HAZARDOUS SITE REMEDIATION ENGINEERING	3.0
CEEN478	WATER TREATMENT DESIGN AND ANALYSIS	3.0
CEEN479	AIR POLLUTION	3.0
CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	3.0
CEEN482	HYDROLOGY AND WATER RESOURCES LABORATORY	3.0
CEEN493	SUSTAINABLE ENGINEERING DESIGN	3.0
Computer Science		
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CSCI306	SOFTWARE ENGINEERING	3.0
CSCI341	COMPUTER ORGANIZATION	3.0
CSCI370	ADVANCED SOFTWARE ENGINEERING	5.0
CSCI400	PRINCIPLES OF PROGRAMMING LANGUAGES	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI410	ELEMENTS OF COMPUTING SYSTEMS	3.0

CSCI422	USER INTERFACES	3.0
CSCI423	COMPUTER SIMULATION	3.0
CSCI425	COMPILER DESIGN	3.0
CSCI436	HUMAN-ROBOT INTERACTION	3.0
CSCI437	INTRODUCTION TO COMPUTER VISION	3.0
CSCI440	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	3.0
CSCI442	OPERATING SYSTEMS	3.0
CSCI443	ADVANCED PROGRAMMING CONCEPTS USING JAVA	3.0
CSCI448	MOBILE APPLICATION DEVELOPMENT	3.0
CSCI455	GAME THEORY AND NETWORKS	3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING	3.0
CSCI471	COMPUTER NETWORKS I	3.0
CSCI473	ROBOT PROGRAMMING AND PERCEPTION	3.0
CSCI475	INFORMATION SECURITY AND PRIVACY	3.0
CSCI477	ELEMENTS OF GAMES AND GAME DEVELOPMENT	3.0
CSCI478	INTRODUCTION TO BIOINFORMATICS	3.0
Electrical Engineering & Electronics		
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG310	INFORMATION SYSTEMS SCIENCE I	3.0
EENG311	INFORMATION SYSTEMS SCIENCE II	3.0
EENG350	SYSTEMS EXPLORATION AND ENGINEERING DESIGN LAB	3.0
EENG383	EMBEDDED SYSTEMS	4.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0
EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS	3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0
EENG390	ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID	3.0
EENG411	DIGITAL SIGNAL PROCESSING	3.0
EENG413	ANALOG AND DIGITAL COMMUNICATION SYSTEMS	4.0
EENG415	DATA SCIENCE FOR ELECTRICAL ENGINEERING	3.0
EENG417	MODERN CONTROL DESIGN	3.0
EENG423	INTRODUCTION TO VLSI DESIGN	3.0
EENG425	INTRODUCTION TO ANTENNAS	3.0
EENG427	WIRELESS COMMUNICATIONS	3.0
EENG428	COMPUTATIONAL ELECTROMAGNETICS	3.0
EENG433	ACTIVE RF & MICROWAVE DEVICES	3.0
EENG430	PASSIVE RF & MICROWAVE DEVICES	3.0
EENG437	INTRODUCTION TO COMPUTER VISION	3.0
EENG470	INTRODUCTION TO HIGH POWER ELECTRONICS	3.0
EENG475	INTERCONNECTION OF RENEWABLE ENERGY, INTEGRATED POWER ELECTRONICS, POWER SYSTEMS, AND POWER QUALITY	3.0
EENG480	POWER SYSTEMS ANALYSIS	3.0
EENG481	ANALYSIS AND DESIGN OF ADVANCED ENERGY SYSTEMS	3.0
EENG486	ELECTROMAGNETIC FIELDS AND WAVES	3.0
EENG489	COMPUTATIONAL METHODS IN ENERGY SYSTEMS AND POWER ELECTRONICS	3.0
PHGN317	SEMICONDUCTOR CIRCUITS- DIGITAL	3.0
Geological Engineering		
GEGN307	PETROLOGY	4.0
GEGN316	FIELD GEOLOGY	5.0
GEGN342	ENGINEERING GEOMORPHOLOGY	3.0
GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN469	ENGINEERING GEOLOGY DESIGN	3.0
GEGN470	GROUND-WATER ENGINEERING DESIGN	3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEGN483	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
Geology		
GEOL308	INTRODUCTORY APPLIED STRUCTURAL GEOLOGY	3.0
GEOL310	EARTH MATERIALS	3.0
GEOL311	MINING GEOLOGY	3.0
GEOL315	SEDIMENTOLOGY AND STRATIGRAPHY	3.0
GEOL321	MINERALOGY AND MINERAL CHARACTERIZATION	3.0
GEOL470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
Mechanical Engineering		
MEGN315	DYNAMICS	3.0
MEGN324	INTRODUCTION TO FINITE ELEMENT ANALYSIS	3.0
MEGN381	MANUFACTURING PROCESSES	3.0
MEGN391	INTRODUCTION TO AUTOMOTIVE DESIGN	3.0
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MEGN416	ENGINEERING VIBRATION	3.0
MEGN417	VEHICLE DYNAMICS & POWERTRAIN SYSTEMS	3.0
MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MEGN451	AERODYNAMICS	3.0
MEGN461	THERMODYNAMICS II	3.0
MEGN466	INTRODUCTION TO INTERNAL COMBUSTION ENGINES	3.0
MEGN467	PRINCIPLES OF BUILDING SCIENCE	3.0
MEGN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MEGN471	HEAT TRANSFER	3.0
MEGN481	MACHINE DESIGN	3.0
Metallurgical and Materials Engineering		
MTGN334	CHEMICAL PROCESSING OF MATERIALS	3.0

MTGN314	PROPERTIES AND PROCESSING OF CERAMICS	2.0
MTGN314L	PROPERTIES AND PROCESSING OF CERAMICS LABORATORY	1.0
MTGN315	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS	3.0
MTGN334L	CHEMICAL PROCESSING OF MATERIALS LABORATORY	1.0
MTGN348	MICROSTRUCTURAL DEVELOPMENT	3.0
MTGN348L	MICROSTRUCTURAL DEVELOPMENT LABORATORY	1.0
MTGN350	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS	3.0
MTGN352	METALLURGICAL AND MATERIALS KINETICS	3.0
MTGN414	ADVANCED PROCESSING AND SINTERING OF CERAMICS	3.0
MTGN419	NON-CRYSTALLINE MATERIALS	3.0
MTGN429	METALLURGICAL ENVIRONMENT	3.0
MTGN430	PHYSICAL CHEMISTRY OF IRON AND STEELMAKING	3.0
MTGN431	HYDRO- AND ELECTRO-METALLURGY	3.0
MTGN442	ENGINEERING ALLOYS	3.0
MTGN445	MECHANICAL PROPERTIES OF MATERIALS	3.0
MTGN445L	MECHANICAL PROPERTIES OF MATERIALS LABORATORY	1.0
MTGN451	CORROSION ENGINEERING	3.0
MTGN456	ELECTRON MICROSCOPY	2.0
MTGN456L	ELECTRON MICROSCOPY LABORATORY	1.0
MTGN461	TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS	3.0
MTGN465	MECHANICAL PROPERTIES OF CERAMICS	3.0
MTGN467	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION	2.0
MTGN468	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION	2.0
MTGN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MTGN472	BIOMATERIALS I	3.0
MTGN473	COMPUTATIONAL MATERIALS	3.0
MTGN475	METALLURGY OF WELDING	2.0
MTGN475L	METALLURGY OF WELDING LABORATORY	1.0
Mining		
MNGN310	EARTH MATERIALS	3.0
MNGN311	MINING GEOLOGY	3.0
MNGN312	SURFACE MINE DESIGN	3.0
MNGN314	UNDERGROUND MINE DESIGN	3.0
MNGN316	COAL MINING METHODS	3.0
MNGN317	DYNAMICS FOR MINING ENGINEERS	1.0
MNGN321	INTRODUCTION TO ROCK MECHANICS	3.0
MNGN333	EXPLOSIVES ENGINEERING I	3.0
MNGN350	INTRODUCTION TO GEOTHERMAL ENERGY	3.0
MNGN406	DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS	3.0
MNGN408	UNDERGROUND DESIGN AND CONSTRUCTION	2.0
MNGN414	MINE PLANT DESIGN	3.0
MNGN418	ADVANCED ROCK MECHANICS	3.0
MNGN422	FLOTATION	2.0
MNGN424	MINE VENTILATION	3.0
MNGN431	MINING AND METALLURGICAL ENVIRONMENT	3.0
MNGN433	MINE SYSTEMS ANALYSIS I	3.0
MNGN436	UNDERGROUND COAL MINE DESIGN	3.0
MNGN461	TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS	3.0
Petroleum Engineering		
PEGN305	COMPUTATIONAL METHODS IN PETROLEUM ENGINEERING	2.0
PEGN308	RESERVOIR ROCK PROPERTIES	3.0
PEGN311	DRILLING ENGINEERING	3.0
PEGN312	PROPERTIES OF PETROLEUM ENGINEERING FLUIDS	3.0
PEGN411	MECHANICS OF PETROLEUM PRODUCTION	3.0
PEGN414	WELL TESTING AND ANALYSIS	3.0
PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	3.0
PEGN423	PETROLEUM RESERVOIR ENGINEERING I	3.0
PEGN424	PETROLEUM RESERVOIR ENGINEERING II	3.0
PEGN426	FORMATION DAMAGE AND STIMULATION	3.0
PEGN438	PETROLEUM DATA ANALYTICS	3.0
PEGN460	FLOW IN PIPE NETWORKS	3.0
PEGN461	SURFACE FACILITIES DESIGN AND OPERATION	3.0
PEGN490	RESERVOIR GEOMECHANICS	3.0

Bachelor of Science in Design Engineering: Focus Areas

Focus Areas are a compilation of prescribed and suggested courses and topical projects that have been reviewed by a broad spectrum of faculty from multiple programs/departments and of varied professional background who assess the collection of content to encompass *technical, innovation, design, social/cultural, and environmental* pillars needed by students who plan to pursue a career in that focus area.

All Focus Areas require a minimum of 18 credits of course work which may include prescribed or recommended engineering courses. In addition to the directed Focus Area coursework, certain HASS and engineering electives may be suggested as supporting the Focus Area. Students should work closely with their advisor to select their electives in a way that complements their Focus Area studies.

In addition to coursework specific to their Focus Area, students must also complete a 6-credit, two-semester capstone senior design project. This project is the culmination of the student’s studies and brings together content learned through the three previous years of Integrative Design Studios, science, mathematics, engineering coursework, and Focus Area coursework.

A limited number of Focus Areas are currently defined. New Focus Areas will be added periodically, depending on student and faculty interest, as described in a separate Design Engineering Program Management document.

Current Focus Areas:

- **Energy Studies** (global energy development, sustainable energy, energy policy)
- **Robotics and Automation**
- **Water Security** (water quality, storage and management, efficient utilization, policy, law)
- **Music, Audio Engineering, and Recording Arts**
- **Corporate Sustainability**
- **Community Development**
- **STEM Teaching**
- **Individualized** (customized course of study)

Focus Area Requirements:

Focus Area – Energy Studies:

Students must take the following courses:

ENGY200	INTRODUCTION TO ENERGY	3.0
ENGY340	NUCLEAR ENERGY	3.0
ENGY350	GEOTHERMAL ENERGY	3.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0
PEGN450	ENERGY ENGINEERING *	3.0

* PEGN450 is also listed in the ENGINEERING ELECTIVE list of courses. Students may not count PEGN450 as an ENGINEERING ELECTIVE credit.

Students must also select one of the following courses:

EBGN330	ENERGY ECONOMICS	3.0
HASS486	SCIENCE AND TECHNOLOGY POLICY **	3.0
HASS490	ENERGY AND SOCIETY **	3.0

** HASS486 and HASS490, if used for Focus Area credits, may not also count toward the 9 credits of required Culture and Society (CAS) Restricted Electives.

Focus Area – Robotics and Automation:

NOTE: *To satisfy pre-reqs* - For their ENGINEERING ELECTIVES courses in students must select CSCI261 (Programming), CSCI262 (Data Structures), EENG284 (Digital).

Students must take the following courses:

MEGN315	DYNAMICS *	3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS *	3.0
EENG383	EMBEDDED SYSTEMS *	4.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0

* MEGN315, EENG307, and EENG383 are also listed in the ENGINEERING ELECTIVE list of courses. Students may not count these three courses as ENGINEERING ELECTIVE credits.

Students must also select two of the following courses:

CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI432	ROBOT ETHICS	3.0
CSCI436	HUMAN-ROBOT INTERACTION	3.0
CSCI437	INTRODUCTION TO COMPUTER VISION	3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING	3.0
MEGN481	MACHINE DESIGN	3.0

Focus Area – Water Security:

NOTE: *To satisfy pre-reqs* - For their ENGINEERING FUNDAMENTALS courses in students must select CHGN209 (Thermo), CEEN310 (Fluids) and CEEN311 (Materials).

Students must take the following courses:

CEEN301	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER *	3.0
CEEN381	HYDROLOGY AND WATER RESOURCES ENGINEERING *	3.0
CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0
CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES	3.0
CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	3.0

* CEEN301 and CEEN381 are also listed in the ENGINEERING ELECTIVE list of courses. Students may not also count these courses as ENGINEERING ELECTIVE courses.

Students must also select one of the following courses:

EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
HASS488	GLOBAL WATER POLITICS AND POLICY **	3.0

** HASS488, if used for Focus Area credits, may not also count toward the 9 credits of Culture and Society (CAS) Restricted Electives.

Focus Area – Music, Audio Engineering, and Recording Arts:

NOTE: *To satisfy pre-reqs* - For their ENGINEERING ELECTIVES courses in students must select EENG307 (Feedback Control) and MEGN315 (Dynamics).

Students must take the following courses**:

HASS324	AUDIO/ACOUSTICAL ENGINEERING AND SCIENCE **	3.0
HASS326	MUSIC THEORY **	3.0
HASS327	MUSIC TECHNOLOGY **	3.0
HASS429	REAL WORLD RECORDING/RESEARCH **	3.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0
MEGN416	ENGINEERING VIBRATION	3.0

** HASS324, HASS326, HASS327, and HASS429 may not also count toward the required 9 credits of Culture and Society (CAS) Restricted Electives.

It is also suggested that students participate in **Performance Enhancement** (3 credits total taken as Free Elective):

LIMU	ENSEMBLE	
LIMU189	INDIVIDUAL INSTRUMENTAL OR VOCAL MUSIC INSTRUCTION	1.0

Focus Area – Community Development:

NOTE: *To satisfy pre-reqs* - For their ENGINEERING ELECTIVES courses in students must select CEEN301 (Fund. of EnvE: Water).

Students must take the following courses:

EDNS315	ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY	3.0
EDNS477	ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT *	3.0
EDNS478	ENGINEERING AND SOCIAL JUSTICE *	3.0
EDNS479	COMMUNITY-BASED RESEARCH *	3.0

* EDNS477, EDNS478, and EDNS479 may not also count toward the 9 credits of Culture and Society (CAS) Restricted Electives.

Students must also select TWO of the following courses:

	ANY 400+ HNRS COURSE	
CEEN401	LIFE CYCLE ASSESSMENT	3.0
CEEN472	ONSITE WATER RECLAMATION AND REUSE	3.0
CEEN475	HAZARDOUS SITE REMEDIATION ENGINEERING	3.0
CEEN479	AIR POLLUTION	3.0
CEEN493	SUSTAINABLE ENGINEERING DESIGN	3.0
CEEN556	MINING AND THE ENVIRONMENT	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
EDNS401	PROJECTS FOR PEOPLE	3.0
HASS419	ENVIRONMENTAL COMMUNICATION	3.0
HASS425	INTERCULTURAL COMMUNICATION **	3.0
HASS427	RISK COMMUNICATION	3.0
HASS468	ENVIRONMENTAL JUSTICE	3.0
HASS490	ENERGY AND SOCIETY	3.0
MNGN470	SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY	3.0
PEGN430	ENVIRONMENTAL LAW AND SUSTAINABILITY	3.0

** HASS425 if used for Focus Area credits, may not also count toward the 9 credits of Culture and Society (CAS) Restricted Electives.

Focus Area – Corporate Sustainability:

NOTE: *To satisfy pre-reqs* - For their ENGINEERING ELECTIVES courses in students must select CEEN301 (Fund. of EnvE: Water).

Students must take the following courses:

EDNS315	ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY	3.0
EDNS430	CORPORATE SOCIAL RESPONSIBILITY **	3.0
EDNS478	ENGINEERING AND SOCIAL JUSTICE	3.0
EDNS479	COMMUNITY-BASED RESEARCH **	3.0

** EDNS430 and EDNS479 may not also count toward the 9 credits of Culture and Society (CAS) Restricted Electives.

Students must also select TWO of the following courses:

	ANY 400+ HNRS COURSE	
CEEN401	LIFE CYCLE ASSESSMENT	3.0
CEEN472	ONSITE WATER RECLAMATION AND REUSE	3.0
CEEN475	HAZARDOUS SITE REMEDIATION ENGINEERING	3.0
CEEN479	AIR POLLUTION	3.0
CEEN493	SUSTAINABLE ENGINEERING DESIGN	3.0
CEEN556	MINING AND THE ENVIRONMENT	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
EDNS401	PROJECTS FOR PEOPLE	3.0
HASS419	ENVIRONMENTAL COMMUNICATION	3.0
HASS425	INTERCULTURAL COMMUNICATION	3.0
HASS427	RISK COMMUNICATION	3.0
HASS468	ENVIRONMENTAL JUSTICE	3.0
HASS490	ENERGY AND SOCIETY	3.0
MNGN470	SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY	3.0
PEGN430	ENVIRONMENTAL LAW AND SUSTAINABILITY	3.0

Focus Area - STEM Teaching:

Students must take the following courses:

SCED262	K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS	3.0
SCED333	EDUCATIONAL PSYCHOLOGY AND ASSESSMENT *	3.0
SCED363	DYNAMIC TEACHING: MOTIVATION, CLASSROOM MANAGEMENT, AND DIFFERENTIATION OF INSTRUCTION *	3.0
SCED464	CAPSTONE CURRICULUM DESIGN I	3.0

* SCED333 and SCED363 may not double-count for both the Focus Area and the Culture and Society (CAS) Restricted Electives

Students must also select one of the following courses:

MAED405	MATHEMATICAL PRACTICES AND THE SOCIAL CONTEXT OF MATHEMATICS	3.0
SCED415	SCIENTIFIC PRACTICES VS ENGINEERING DESIGN AND THE NATURE OF SCIENCE	3.0

Students must also select one of the following courses:

MAED425	PRE-ALGEBRA AND ALGEBRA TEACHING TECHNIQUES	3.0
SCED445	PHYSICS AND CHEMISTRY TEACHING TECHNIQUES	3.0

Focus Area – Individualized Focus Areas:

An Individualized Focus Area (IFA) is a customized course of study along with an associated senior design capstone experience that is agreed upon by the student, advisor, and Design Engineering Program Director. Typically, an IFA is defined for a student whose interests and passions are not represented by the existing predefined Focus Areas. The advisor and Design Engineering Program Director are responsible for ensuring an IFA meets the same standards as any of the predefined Focus Areas in the Design Engineering program, as described below in the Program Management section, including having at least three faculty mentors. The transcripts of students who follow an IFA will be denoted as “Individualized Focus Area” without further reference to the focus topic.

Major GPA

The Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree’s GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree’s GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- EDNS100 through EDNS599

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Minor in Engineering for Community Development

Program requirements (18 credits)

Introductory Courses (9 credits required):		
EDNS315	ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY	3.0
EDNS478	ENGINEERING AND SOCIAL JUSTICE	3.0
EDNS479	COMMUNITY-BASED RESEARCH	3.0
ECD Required Course (3 credits required):		
EDNS477	ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT	3.0
CAS Elective (3 credits from this list):		
ANY 400+ HNRS COURSE		
HASS419	ENVIRONMENTAL COMMUNICATION	3.0
HASS425	INTERCULTURAL COMMUNICATION	3.0
HASS427	RISK COMMUNICATION	3.0
HASS468	ENVIRONMENTAL JUSTICE	3.0
HASS490	ENERGY AND SOCIETY	3.0
OR AN CAS COURSE APPROVED BY MINOR DIRECTOR AS APPROPRIATE		
Elective (3 credits from this list):		
EDNS401	PROJECTS FOR PEOPLE	3.0
PEGN430	ENVIRONMENTAL LAW AND SUSTAINABILITY	3.0
CEEN401	LIFE CYCLE ASSESSMENT	3.0
CEEN472	ONSITE WATER RECLAMATION AND REUSE	3.0
CEEN493	SUSTAINABLE ENGINEERING DESIGN	3.0
CEEN479	AIR POLLUTION	3.0
CEEN475	HAZARDOUS SITE REMEDIATION ENGINEERING	3.0
CEEN556	MINING AND THE ENVIRONMENT	3.0
MNGN470	SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
OR A COURSE APPROVED BY MINOR DIRECTOR AS APPROPRIATE		

Minor in Leadership in Social Responsibility

The Minor in Leadership in Social Responsibility will prepare CSM students to become leaders in identifying and promoting the role that engineers can play in advancing social responsibility inside corporations. Graduates will be able to articulate the strategic value of social responsibility for business, particularly in achieving and maintaining the social license to operate, and the role engineering itself can play in advancing a firm’s social responsibility program, including community engagement.

For CSM students to “solve the world’s challenges related to the earth, energy, and the environment,” they must also be able to navigate the increasingly complex social, political, and economic contexts that shape those challenges. Achieving the social license to operate, for example, is recognized as necessary for developing mineral resources in the U.S. and abroad. Stewardship of the earth, development of materials, overcoming the earth’s energy challenges, and fostering environmentally sound and sustainable solutions – the bedrock of the Mines vision articulated in the Strategic Plan – requires engineers and applied scientists who are able to work in local and global contexts that are shaped by the sometimes conflicting demands of stakeholders, governments, communities and corporations. Reasoning through and managing these competing demands is at the core of social responsibility.

Minor in Leadership in Social Responsibility (18 credits required)

Introductory Courses (9 credits required):		
EDNS315	ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY	3.0
EDNS478	ENGINEERING AND SOCIAL JUSTICE	3.0
EDNS479	COMMUNITY-BASED RESEARCH	3.0
LSR Required Course (3 credits required):		
EDNS430	CORPORATE SOCIAL RESPONSIBILITY	3.0
CAS Elective (3 credits from this list):		
ANY 400+ HNRS COURSE		
HASS419	ENVIRONMENTAL COMMUNICATION	3.0
HASS425	INTERCULTURAL COMMUNICATION	3.0
HASS427	RISK COMMUNICATION	3.0
HASS468	ENVIRONMENTAL JUSTICE	3.0
HASS490	ENERGY AND SOCIETY	3.0
OR AN CAS COURSE APPROVED BY MINOR DIRECTOR AS APPROPRIATE		
Elective (3 credits from this list):		

CEEN401	LIFE CYCLE ASSESSMENT	3.0
CEEN472	ONSITE WATER RECLAMATION AND REUSE	3.0
CEEN475	HAZARDOUS SITE REMEDIATION ENGINEERING	3.0
CEEN479	AIR POLLUTION	3.0
CEEN493	SUSTAINABLE ENGINEERING DESIGN	3.0
CEEN556	MINING AND THE ENVIRONMENT	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
EDNS401	PROJECTS FOR PEOPLE	3.0
MNGN470	SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY	3.0
PEGN430	ENVIRONMENTAL LAW AND SUSTAINABILITY	3.0
OR A COURSE APPROVED BY MINOR DIRECTOR AS APPROPRIATE		

Area of Special Interest in Humanitarian Engineering (12 credits)

Intro Course		**3.0**
EDNS315	ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY	
Select one of the following:		**3.0**
EDNS301	HUMAN-CENTERED PROBLEM DEFINITION	
EDNS401	PROJECTS FOR PEOPLE	
EDNS430	CORPORATE SOCIAL RESPONSIBILITY	
Select two of the following:		**6.0**
EDNS477	ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT	
EDNS478	ENGINEERING AND SOCIAL JUSTICE	
EDNS479	COMMUNITY-BASED RESEARCH	
EDNS480	ANTHROPOLOGY OF DEVELOPMENT	
HASS425	INTERCULTURAL COMMUNICATION	
CEEN493	SUSTAINABLE ENGINEERING DESIGN	

Courses

EDNS151. CORNERSTONE - DESIGN I. 3.0 Semester Hrs.
Equivalent with EPIC151,
(I, II, S) Design I teaches students how to solve open-ended problems in a hands-on manner using critical thinking and workplace skills. Students work in multidisciplinary teams to learn through doing, with emphasis on defining and diagnosing the problem through a holistic lens of technology, people and culture. Students follow a user-centered design methodology throughout the process, seeking to understand a problem from multiple perspectives before attempting to solve it. Students learn and apply specific skills throughout the semester, including: communication (written, oral, graphical), project management, concept visualization, critical thinking, effective teamwork, as well as building and iterating solutions.
Course Learning Outcomes

- 1. Identify, breakdown, and define open-ended problems.
- 2. Research the context and background of problems and solutions, including user needs and technical requirements, through scholarly and authoritative sources, and stakeholder input.
- 3. Design solutions through a cycle of testing, refining, iterating, and feedback.
- 4. Equitably contribute to team efforts from start to end on a collaborative project, and participate in learning activities and coaching activities in the team.
- 5. Apply common workplace practices, tools and software in a semester-long team project, including project planning tools, team management tools, tools to generate solution alternatives, decision analysis methods, risk analysis methods, and value proposition analysis/baseline comparison.
- 6. Present technical ideas and solutions graphically, orally, written, and through prototype demonstrations
- 7. Visually depict ideas to teammates, supervisors, and stakeholders through the use of field sketching for the purposes of communication as well as idea development and development through iteration.
- 8. Model and communicate formalized design ideas through the use of standardized engineering graphics conventions as applied to engineering sketching and computer-aided design/solid modeling software

EDNS155. CORNERSTONE DESIGN I: GRAPHICS. 1.0 Semester Hr.
Equivalent with EPIC155,
(I ,II, S) Design I: Graphics teaches students conceptualization and visualization skills, and how to represent ideas graphically, both by hand and using computer aided design (CAD).
Course Learning Outcomes

- 8) Use engineering graphics conventions as applied to technical sketching and computer-aided design/solid modeling software to communicate formalized design ideas.

EDNS156. AUTOCAD BASICS. 1.0 Semester Hr.
(I, II) This course explores the two- and three-dimensional viewing and construction capabilities of AutoCAD. Students will learn to use AutoCAD for modeling (2D line drawing, 3D construction, Rendering, Part Assembly) and will develop techniques to improve speed and accuracy. The AutoCAD certification exam will not be offered as part of this course; however, the professor will provide instructions on accessing certification options, which generally have their own fees associated with them. 3 hours lab; 1 semester hour.
Course Learning Outcomes

- 1- Identify the components of the AutoCAD user interface and basic CAD terminology.
- 2- Apply basic concepts to develop construction (drawing) techniques.
- 3- Manipulate drawings through editing and plotting techniques.
- 4- Apply geometric construction and produce 2D Orthographic Projections.
- 5 - Interpret dimensions and demonstrate dimensioning concepts and techniques.
- 6- Reuse existing content and become familiar with the use of Blocks.
- 7- Explore the three-dimensional viewing and construction capabilities of AutoCAD.
- 8- Create and edit 3D Models from 2D profiles. Extract 2D views from a 3D model for detail drafting.

EDNS157. SOLIDWORKS BASICS (FOR CERTIFICATION). 1.0 Semester Hr.
(I, II) Students will become familiar and confident with Solidworks CAD program and be able to use most of the basic functions well, including Parts, Assemblies, and Drawing Layouts. The Associate-level certification exam will be offered at the end of the course, and while there are no

guarantees for students becoming certified, students will have gained the necessary skills to try. 3 hours lab; 1 semester hour.

Course Learning Outcomes

- 1- Identify the components of the Solidworks user interface and basic CAD terminology and approaches.
- 2- Apply basic solid modeling concepts and use the basic part modeling functionality of Solidworks software.
- 3 - Develop defined and valid advanced 2 D sketch profiles in Solidworks for use in 3D operations and features.
- 4- Apply basic technical drawing concepts to interpret technical drawings for part modeling.
- 5 - Demonstrate dimensioning concepts and techniques by interpreting and creating properly annotated technical drawings.
- 6 - Identify and apply the techniques of 3D models such as revolve, sweep, and loft features.
- 7 - Identify geometric relations and functions of an assembly design to virtually assembly a set of parts into an assembly.
- 8 -Extract two-dimensional views from a three-dimensional model and assembly for detail drafting

EDNS191. INTRODUCTION TO INTEGRATIVE DESIGN. 3.0 Semester Hrs.

Students are introduced to human-centered design methodologies relative to open-ended problem solving using socially relevant challenges. Students in this first design studio course utilize a range of resources to explore ethical implications and test the logic of arguments for/against proposed design solutions. Hands-on activities and graphical visualization are utilized to approach the design process in a collaborative team environment. Students begin compiling a personal design portfolio that carries through their undergraduate studies for the Bachelor of Science in Design Engineering degree.

EDNS192. DESIGN AND HUMAN VALUES. 4.0 Semester Hrs.

Students explore and participate in design activities as an individual or on smaller teams. Projects include the design of experiential activities or community projects. Students evaluate the history of science and engineering and its impact on social and political systems as a foundation for creating smarter designs. Prototyping skills are utilized to explore design functionality and potential alternatives. The course emphasizes technical writing along with the development of other communication formats. Prerequisite: EDNS191 or EDNS151.

EDNS198. SPECIAL TOPCS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EDNS199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EDNS199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EDNS200. INTRODUCTION TO DESIGN ENGINEERING. 3.0 Semester Hrs.

Students are introduced to the unique ways designers frame complex open-ended problems, engage with end users, and develop solutions to meet the needs of diverse stakeholders. Students are introduced to designers' creative communication strategies, including basic techniques for written, oral, graphic, and tangible product communication. Students will engage in individual and team-based projects, honing their design identity as well as their unique contributions to collaborative challenges. With extensive opportunity for design feedback and iteration, students learn to produce and analyze design artifacts for varied audiences and contexts. 5 studio hours; 3 semester hours. Co-requisite: HASS100.

Course Learning Outcomes

- 1. Recognize and apply the ways in which communication functions: how, for whom, via what means, toward what ends, and for what purpose.
- 2. Reflect on positionality and its influence on interpretation, design, and communication of information.
- 3. Execute effective design through evaluation of stakeholder needs, use of oral, written, or graphical communication, completion of hands-on demonstrations or prototyping.
- 4. Understand the best methods for addressing challenges associated with user-centered design, communicating technical content to a non-technical audience, and verification of effective design artifacts.

EDNS205. PROGRAMMING CONCEPTS AND ENGINEERING ANALYSIS. 3.0 Semester Hrs.

(I,II) This course provides an introduction to techniques of scientific computation that are utilized for engineering analysis, with the software package MATLAB as the primary computational platform. The course focuses on methods data analysis and programming, along with numerical solutions to algebraic and differential equations. Engineering applications are used as examples throughout the course. 3 hours lecture; 3 semester hours.

EDNS251. CORNERSTONE DESIGN II. 3.0 Semester Hrs.

Equivalent with EPIC251,

Design II builds on the design process introduced in Design I, which focuses on open-ended problem solving in which students integrate teamwork and communications with the use of design techniques, business tools, and computer software to solve engineering problems. Student project teams now work with real-world clients while infusing introductory business skills including Agile project management tools, time-value of money and financial project justifications to address client needs. Computer applications emphasize data analytics. Teams build team dynamics and ensure satisfaction of client needs through team meetings and sprint reviews. The course emphasizes oral, visual, and written technical communications techniques introduced in Design I. 2 hours lecture, 3 hours lab; 3 semester hours. Prerequisite: EDNS151, EDNS155, HNRS115, or HNRS120.

Course Learning Outcomes

- 1. Identify, breakdown, and define open-ended problems.
- 2. Research the context and background of problems and solutions, including user needs and technical requirements, through scholarly and authoritative sources, and stakeholder input.
- 3. Design solutions through a cycle of testing, refining, iterating, and feedback.

- 4. Equitably contribute to team efforts from start to end on a collaborative project, and participate in learning activities and coaching activities in the team.
- 5. Apply common workplace practices, tools and software in a semester-long team project, including project planning tools, team management tools, tools to generate solution alternatives, decision analysis methods, risk analysis methods, and value proposition analysis/baseline comparison.
- 6. Present technical ideas and solutions graphically, orally, written, and through prototype demonstrations.
- 7. Manage a client relationship, including communicating, soliciting and incorporating input, and delivering a solution that meets client requirements and constraints.
- 8. Use commercial software to create user interfaces or to collect data for accurate analyses as well as to make reasonable decisions and/or predictive models.

EDNS291. DESIGN UNLEASHED. 3.0 Semester Hrs.
Students explore design as an approach to the world through a series of creative, hands-on projects. Projects are defined through designer goals and evaluated through iterative solution posing. This course investigates how design engineers frame open-ended problems and communicate design solutions. Multiple design challenges encourage the utilization of a variety of tools to further develop and iterate on design solutions and product verification. 5 studio hours; 3 semester hours Prerequisite: HNRS115 or HASS100, EDNS151. Co-requisite: EDNS200.

EDNS292. DESIGN FOR A GLOBALIZED WORLD. 3.0 Semester Hrs.
This experiential design course focuses on how designers respond to increasing global interdependencies and diverse global cultures. Through a variety of design activities, students engage in systems thinking, strategic social planning, and sustainability analysis while applying skills toward reconciling competing perspectives, goals, and needs. The course also explores students place in the world and their responsibilities as design engineers, global thinkers, and interdisciplinary problem solvers. Prerequisite: EDNS200, EDNS291.

EDNS298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EDNS299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Variable credit; 1 to 6 credit hours. Repeatable for credit. Prerequisite: Independent Study form must be completed and submitted to the Registrar.

EDNS301. HUMAN-CENTERED PROBLEM DEFINITION. 3.0 Semester Hrs.
(I, II) This class will equip students with the knowledge, skills and attitudes needed to identify, define, and begin solving real problems for real people, within the socio-technical ambiguity that surrounds all engineering problems. The course will focus on problems faced in everyday life, by people from different backgrounds and in different circumstances, so that students will be able to rise to the occasion presented by future workplace challenges. By the end of this course, students will be able to recognize design problems around them, determine whether they are worth solving, and employ a suite of tools to create multiple solutions. The follow up course --"Design for People" -- will enable students to take the best solutions to the prototype phase. 3 hours lecture; 3 semester hours.

EDNS315. ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY. 3.0 Semester Hrs.
(WI) This course explores how engineers think about and practice environmental and social responsibility, and critically analyzes codes of ethics before moving to a deeper focus on macroethical topics with direct relevance to engineering practice, environmental sustainability, social and environmental justice, social entrepreneurship, corporate social responsibility, and engagement with the public. These macroethical issues are examined through a variety of historical and contemporary case studies and a broad range of technologies. Prerequisite: HASS100, and EDNS151 or EDNS192. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Identify and connect key moments in the history of engineering professions related to environmental and social responsibilities with current engineering challenges, particularly from the 20th century through current day, and how the idea of “responsibility” in the engineering profession has changed throughout this history
- Define key terms that relate the engineering professions’ environmental and social responsibilities
- Identify stakeholders in engineering projects, and analyze their roles, perspectives, and implications in environmental and social responsibility from various sectors and disciplines
- Critique pervasive engineering mindsets and their relationship to engineers’ responsibilities; where these attitudes and approaches are first established and subsequently reinforced through educational and professional practice
- Create and develop persuasive arguments for practical steps to promote environmental and social responsibility in engineering projects, using professional tools for risk analysis, life cycle assessment, and cost/benefit while recognizing the limitations of any numerical simplification

EDNS391. DESIGN & MODELING OF INTEGRATED SYSTEMS. 3.0 Semester Hrs.
Complex problems in areas of healthcare, transportation, energy distribution, communication require an integrative solution spanning technical, social, and environmental perspectives.. In this course, students develop an appreciation of systems thinking as a holistic approach to complex problem solving. Students will engage with systems thinking in a way that recognizes the whole of the problem through analyzing interrelationships, attributes, and effects. Students apply systems thinking perspectives to a socio-technical problem, describe the problem through modeling techniques, design a holistic solution, and improve upon the solution through justification and systems thinking approaches. Prerequisite: EDNS292.

EDNS392. DESIGN ENGINEERING APPLICATIONS. 3.0 Semester Hrs.
Being a successful design engineer requires an interdisciplinary outlook, the ability to apply practical and conceptual design tools, and sound analytic judgment. This course culminates the integrative design studio sequence, which explores design techniques; problem-definition-and-solution in complex social, cultural, and political contexts; and the professional design ecosystems in which engineers work. The course offers an advanced opportunity to pair design theory with hands-on design projects, while also being attentive to a systems-approach for engineering design. The course emphasizes professional preparedness by refining students? skills in needs assessment, integrated modes of feasibility analysis, and contextualizing proposed solutions. The course allows students to refine their design engineering competencies and identities while simultaneously clarifying their career goals and preparing

for a more meaningful Capstone Design experience. 5 studio hours; 3 semester hours. Prerequisite: EDNS391.

Course Learning Outcomes

- 1. Apply design process elements - including stakeholder engagement, iteration, hands-on skills, relevant background research, and engineering analysis within multiple contexts
- 2. Apply systems, logical, and critical thinking skills. This includes interpreting, analyzing, synthesizing, and using multiple perspectives and alternatives in your work, and identification of relevant "code of ethics" in action; creating strong arguments to support your decisions; and making judgments.
- 3. . Examine design variables and impact on global, social, environmental, or economic contexts

EDNS398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EDNS399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EDNS401. PROJECTS FOR PEOPLE. 3.0 Semester Hrs.
(I, II) Work with innovative organizations dedicated to community development to solve major engineering challenges. This course is open to juniors and seniors interested in engaging a challenging design problem and learning more about Human Centered Design (HCD). The course will be aimed at developing engineering solutions to real problems affecting real people in areas central to their lives. 3 hours lecture; 3 semester hours.

EDNS430. CORPORATE SOCIAL RESPONSIBILITY. 3.0 Semester Hrs.
Equivalent with LAIS430,
Businesses are largely responsible for creating the wealth upon which the well-being of society depends. As they create that wealth, their actions impact society, which is composed of a wide variety of stakeholders. In turn, society shapes the rules and expectations by which businesses must navigate their internal and external environments. This interaction between corporations and society (in its broadest sense) is the concern of Corporate Social Responsibility (CSR). This course explores the dimensions of that interaction from a multi-stakeholder perspective using case studies, guest speakers and field work. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

EDNS477. ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT. 3.0 Semester Hrs.
This course is an introduction to the relationship between engineering and sustainable community development (SCD) from historical, political, ideological, ethical, cultural, and practical perspectives. Students will study and analyze different dimensions of community and sustainable development and the role that engineering might play in them. Also students will critically explore strengths and limitations of dominant methods in engineering problem solving, design, and research for working in SCD. Students will learn to research, describe, analyze and evaluate case studies in SCD and develop criteria for their evaluation. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

Course Learning Outcomes

- Varies by semester

EDNS478. ENGINEERING AND SOCIAL JUSTICE. 3.0 Semester Hrs.
Equivalent with LAIS478,
This course offers students the opportunity to explore the relationships between engineering and social justice. The course begins with students? exploration of their own social locations, alliances and resistances to social justice through critical engagement of interdisciplinary readings that challenge engineering mindsets. Then the course helps students to understand what constitutes social justice in different areas of social life and the role that engineers and engineering might play in these. Finally, the course gives students an understanding of why and how engineering has been aligned and/or divergent from social justice issues and causes. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

EDNS479. COMMUNITY-BASED RESEARCH. 3.0 Semester Hrs.
Engineers and applied scientists face challenges that are profoundly socio-technical in nature, and communities are increasingly calling for greater participation in the decisions that affect them. Understanding the diverse perspectives of communities and being able to establish positive working relationships with their members is therefore crucial to the socially responsible practice of engineering and applied science. This course provides students with the conceptual and methodological tools to conduct community-based research. Students will learn ethnographic field methods and participatory research strategies, and critically assess the strengths and limitations of these through a final original research project. Prerequisite: HASS100 or graduate student standing. Co-requisite: HASS200 or graduate student standing.

EDNS480. ANTHROPOLOGY OF DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS480,
Engineers and applied scientists face challenges that are profoundly socio-technical in nature, ranging from controversies surrounding new technologies of energy extraction that affect communities to the mercurial "social license to operate" in locations where technical systems impact people. Understanding the perspectives of communities and being able to establish positive working relationships with their members is therefore crucial to the socially responsible practice of engineering and applied science. This course provides students with the conceptual and methodological tools to engage communities in respectful and productive ways. Students will learn ethnographic field methods and participatory research strategies, and critically assess the strengths and limitations of these through a final original research project. Prerequisite: HASS200. Co-requisite: EDNS477 or HASS325.

EDNS491. CAPSTONE DESIGN I. 3.0 Semester Hrs.
Equivalent with EGGN491,
(WI) This course is the first of a two-semester capstone course sequence giving the student experience in the engineering design process. Realistic open-ended design problems are addressed for real world clients at the conceptual, engineering analysis, and the synthesis stages and include economic and ethical considerations necessary to arrive at a final design. Students are assigned to interdisciplinary teams and exposed to processes in the areas of design methodology, project management, communications, and work place issues. Strong emphasis is placed on this being a process course versus a project course. This is a writing-across-the-curriculum course where students' written and oral communication skills are strengthened. The design projects are chosen to develop student creativity, use of design methodology and application of prior course work paralleled by individual study and research. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: For BSME students,

completion of MEGN301; for BSCE students, completion of Engineering Field Session, Civil, CEEN 331; for BSENV completion of Engineering Field Session, Environmental, CEEN 330; and for all other students completion of Field Session appropriate to the student's specialty and consent of instructor. Co-requisite: For BSME students, MEGN481; for BSCE students, any one of CEEN443, CEEN445, CEEN442, or CEEN415; for BSEE students, EENG 350 and EENG 389 plus any one of EENG 391, EENG 392, EENG 393, or EENG 394; for BSE students, EDNS392.

Course Learning Outcomes

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EDNS492. CAPSTONE DESIGN II. 3.0 Semester Hrs.

(WI) This course is the second of a two-semester sequence to give the student experience in the engineering design process. Design integrity and performance are to be demonstrated by building a prototype or model, or producing a complete drawing and specification package, and performing pre-planned experimental tests, wherever feasible, to verify design compliance with client requirements. 1 hour lecture; 6 hours lab; 3 semester hours. Prerequisite: EDNS491.

EDNS498. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EDNS499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Department Heads

Dean Nieusma, Department Head

Chelsea Salinas, Assistant Department Head; Director of Design Engineering Program

Professors

Kevin Moore, Executive Director of Humanitarian Engineering

Juan Lucena, Humanitarian Engineering Director of Undergraduate Programs and Outreach

Jessica Smith

Assistant professors

Elizabeth Reddy , Assistant Director of Humanitarian Engineering and Science Interdisciplinary Graduate Program

Marie Stettler Kleine

Teaching Professors

Yosef Allam, Director of Cornerstone Design Program

Alina Handorean

Teaching Associate Professors

Jack Bringardner

Mirna Mattjik

Mark Orrs

Sid Saleh, Director of McNeil Center for Entrepreneurship & Innovation

Kate Youmans, Presidential Faculty Fellow for Diversity, Inclusion & Access

Teaching Assistant Professors

Cynthia Athanasiou

Duncan Davis-Hall

Michael Sheppard

Aubrey Wigner

Professor of Practice

Donna Bodeau

Garrett Erickson

Antonie Vandenberge

Staff

Becky Buschke, Program Assistant

Leah Fitzgerald, Stakeholder Relations Manager

Kirsten Kelly, Capstone Administrative Assistant

Julia Roos, Associate Director of Humanitarian Engineering

Kimberly Walker, Department Manager

Electrical Engineering

Program Description

The Department of Electrical Engineering at Mines strives to produce leaders who serve the profession, the global community, and society. Students attain technical expertise while completing coursework and projects reflective of modern technology trends. Students consider the broader impacts of engineering solutions on society and human lives. Fundamental and applied engineering research in power and renewable energy, data sciences and control systems, and RF and wireless communications are offered which support the university's mission of "earth, energy, and environment."

At the undergraduate level, the department focuses on a select number of areas in electrical engineering; specifically,

1. Power and energy systems (PES).
2. Integrated circuits, computer engineering and electronic systems (ICE).
3. Information and systems sciences (ISS).
4. Antennas and wireless communications (AWC).

At the graduate level, the department provides educational and research opportunities in three selected topical areas:

1. compressive sensing, data analysis, control and optimization.
2. energy systems, electric power, power electronics, renewable energy, machines and drives.

3. antennas, RF and microwaves, wireless communications, and computational electromagnetics.

Both undergraduate and graduate programs are characterized by strong ties with industrial partners (locally and nationally) that provide resources for students, laboratories, research projects, and ultimately career paths for our students.

BS in Electrical Engineering

The Bachelor of Science in Electrical Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission’s General Criteria and Program Criteria for Electrical, Computer, Communications, Telecommunication(s).

PROGRAM EDUCATIONAL OBJECTIVES

The Electrical Engineering program contributes to the educational objectives described in the Mines' Graduate Profile. In addition, the Electrical Engineering Program at Mines has established the following program educational objectives:

Within three years of attaining the BSEE degree:

1. Graduates will be applying their professional Electrical Engineering skills and training in their chosen field or will be successfully pursuing a degree.
2. Graduates will be situated in growing careers, generating new knowledge and exercising professional leadership.
3. Graduates will be contributing to the needs of society through professional practice, research and service.

STUDENT OUTCOMES

To accomplish these objectives, the Electrical Engineering program has adopted the following Student Outcomes (SO) articulated by ABET:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. an ability to communicate effectively with a range of audiences.
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

These Program Educational Objectives and Student Outcomes can be found on the Electrical Engineering Department's website under the Colorado School of Mines website.

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4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Bachelor of Science in Electrical Engineering Degree Requirements:

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
Science Elective	CBEN110, GEGN101, CHGN122, or CHGN125			4.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0

		lec	lab	sem.hrs
PHGN100	PHYSICS I - MECHANICS			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
				15.0

Sophomore

Fall		lec	lab	sem.hrs
HASS200	GLOBAL STUDIES			3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS (Distributed Science 3)			4.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
SUCCESS +WELLNESS	Choose one course from the following: CSM250 (1.0 credit), CSM275 (1 credit), CSM350 (3 credits), or PAGN2XX (1 credit)			1.0
				15.0

Spring		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
EENG284	DIGITAL LOGIC			4.0
EENG282	ELECTRICAL CIRCUITS			4.0
FREE ELECTIVE				3.0
				17.0

Junior

Fall		lec	lab	sem.hrs
MATH332	LINEAR ALGEBRA			3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS			3.0
EENG310	INFORMATION SYSTEMS SCIENCE I			3.0
EENG383	EMBEDDED SYSTEMS			4.0
EENG391	FE ON COMPUTATIONAL METHODS FOR ELECTRICAL ENGINEERING			1.0
EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS			3.0
				17.0

Spring		lec	lab	sem.hrs
EENG385	ELECTRONIC DEVICES AND CIRCUITS			4.0
EENG311	INFORMATION SYSTEMS SCIENCE II			3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY			4.0
EE ELECTIVE	Students must complete 15 credits of Electrical Engineering Electives from the approved list in the 2023-2024 catalog.			3.0
EENG350	SYSTEMS EXPLORATION AND ENGINEERING DESIGN LAB			3.0
				17.0

Senior

Fall		lec	lab	sem.hrs
CAS Elective	Culture and Society (CAS) Mid-Level Restricted Elective			3.0
CAS Elective	Culture and Society (CAS) Mid-Level Restricted Elective			3.0
EDNS491	CAPSTONE DESIGN I			3.0
EE Elective	Electrical Engineering Elective *			3.0
EE Elective	Electrical Engineering Elective *			3.0
EENG392	FE ON INFORMATION AND SYSTEMS SCIENCES, 393, or 394			1.0
				16.0

Spring		lec	lab	sem.hrs
CAS Elective	Culture and Society (CAS) 400-Level Restricted Elective			3.0
EDNS492	CAPSTONE DESIGN II			3.0
EE Elective	Electrical Engineering Elective *			3.0
EE ELECTIVE	Electrical Engineering Elective *			3.0
FREE ELECTIVE				3.0
				15.0

Total Semester Hrs: 128.0

* Electrical Engineering students are required to take five Electrical Engineering electives from an approved list. See below for guidelines and the list of Electrical Engineering electives:

Electrical Engineering Electives:

These Electrical Engineering electives are open to all EE students. The interest pathways they fall under are: Information and Systems Science (ISS), Power and Energy Systems (PES), Integrated Circuits and Electronics (ICE), and Antennas and Wireless Communications (AWC).

Electrical Engineering students are required to complete 15 credits of Electrical Engineering electives. At least 9 credits out of the 15 must be 400-level or higher EENG-prefix courses.

EENG390	ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID	3.0
EENG411	DIGITAL SIGNAL PROCESSING	3.0
EENG413	ANALOG AND DIGITAL COMMUNICATION SYSTEMS	4.0
EENG415	DATA SCIENCE FOR ELECTRICAL ENGINEERING	3.0
EENG417	MODERN CONTROL DESIGN	3.0
EENG421	SEMICONDUCTOR DEVICE PHYSICS AND DESIGN	3.0
EENG423	INTRODUCTION TO VLSI DESIGN	3.0
EENG425	INTRODUCTION TO ANTENNAS	3.0
EENG427	WIRELESS COMMUNICATIONS	3.0
EENG428	COMPUTATIONAL ELECTROMAGNETICS	3.0
EENG430	PASSIVE RF & MICROWAVE DEVICES	3.0
EENG433	ACTIVE RF & MICROWAVE DEVICES	3.0
EENG437	INTRODUCTION TO COMPUTER VISION	3.0
EENG470	INTRODUCTION TO HIGH POWER ELECTRONICS	3.0
EENG475	INTERCONNECTION OF RENEWABLE ENERGY, INTEGRATED POWER ELECTRONICS, POWER SYSTEMS, AND POWER QUALITY	3.0
EENG480	POWER SYSTEMS ANALYSIS	3.0
EENG481	ANALYSIS AND DESIGN OF ADVANCED ENERGY SYSTEMS	3.0
EENG486	ELECTROMAGNETIC FIELDS AND WAVES	3.0
EENG489	COMPUTATIONAL METHODS IN ENERGY SYSTEMS AND POWER ELECTRONICS	3.0
CSCI341	COMPUTER ORGANIZATION	3.0
CSCI410	ELEMENTS OF COMPUTING SYSTEMS	3.0
CSCI440	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	3.0
CSCI442	OPERATING SYSTEMS	3.0
CEEN405	NUMERICAL METHODS FOR ENGINEERS	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS	4.0
PHGN435	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
PHGN440	SOLID STATE PHYSICS	3.0
PHGN441	SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA	3.0
PHGN462	ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS	3.0

*EE graduate level courses may count towards undergraduate Electrical Engineering Electives; however, undergraduate students must secure instructor approval to enroll in graduate level courses and a course exception request is required for graduate courses to fulfill undergraduate EE electives. Additional 400-level and graduate-level classes taught by faculty in the EE department may be considered on a case-by-case basis as Electrical Engineering electives. Talk to your advisor for further guidance.

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- EENG100 through EENG699 inclusive
- EDNS491 (EGGN491)
- EDNS492 (EGGN492)

Combined BS/MS in Electrical Engineering

The Department of Electrical Engineering offers a Combined Bachelor of Science/Master of Science program in Electrical Engineering that enables students to begin working on an MS degree while completing their BS degree. Students enrolled in Mines' combined undergraduate/graduate program may double count up to six credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with "B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

Students must be admitted into the combined BS/MS degree program at least one term before their expected graduation date. For example: Apply to the spring 2025 entry term on your Combined Application if you are graduating in May of 2025. This application will be completed in the fall of 2024. Students may apply as early as the first semester of their junior year, upon completion of 60 hours of undergraduate course work. In order to apply for the combined program, a graduate school application must be submitted, and as long as the undergraduate portion of the program is successfully completed and the student has a GPA above 3.0, the student is admitted to the non#thesis Master of Science degree program in Electrical Engineering.

Students are required to take an additional 30 credits for the MS degree. Students should follow the MS non#thesis degree requirements based on their track in selecting appropriate graduate degree courses. Students may switch from the combined program which includes a non-thesis Master of Science degree to an MS degree with a thesis optional, however, if students change degree programs they must satisfy all degree requirements for the MS with thesis degree.

Combined Engineering Physics Baccalaureate and Electrical Engineering Master's Degrees

The Department of Electrical Engineering, in collaboration with the Department of Physics, offers a five-year program in which students have the opportunity to obtain specific engineering skill to complement their physics background. Physics students in this program fill in their technical and free electives over their standard four-year Engineering Physics BS program with a reduced set of Electrical Engineering classes. At the end of the fourth year, the student is awarded an Engineering Physics BS degree. Course schedules for this five-year program can be obtained in the Physics departmental offices.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Electrical Engineering

ASI in Electrical Engineering

The following 12-credit sequence is required for an ASI in Electrical Engineering, The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER	3.0
or PHGN215	ANALOG ELECTRONICS	
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
Complete remaining requirements by taking 6 credits of any EENG 300 or 400-level course.		

Minor in Electrical Engineering

A minimum of 18 credits are required for a Minor in Electrical Engineering as follows. (See Minor/ASI section of the Bulletin for all rules for minors at Mines.)

Students must complete an 18-credit sequence as described below for a minor in EE. All students seeking a minor in EE will need to take EENG282 (4 credits) and EENG307 (3 credits) after which they complete the remaining minor requirements.

1. Information Systems and Science (ISS), 18 or 20 credits

EENG282	ELECTRICAL CIRCUITS	4.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG284	DIGITAL LOGIC	4.0
EENG310	INFORMATION SYSTEMS SCIENCE I	3.0
EENG311	INFORMATION SYSTEMS SCIENCE II	3.0

2. Power and Energy Systems (PES), 18 credits

EENG282	ELECTRICAL CIRCUITS	4.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0
EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS	3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0

3. Digital Systems, 18 or 20 credits

EENG282	ELECTRICAL CIRCUITS	4.0
or EENG281 & MEGN300	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER and INSTRUMENTATION & AUTOMATION	
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG284	DIGITAL LOGIC	4.0
EENG383	EMBEDDED SYSTEMS	4.0
EENG421	SEMICONDUCTOR DEVICE PHYSICS AND DESIGN	3.0
or EENG423	INTRODUCTION TO VLSI DESIGN	

4. General Electrical Engineering, 19 or 21 credits

EENG282	ELECTRICAL CIRCUITS	4.0
or EENG281 & MEGN300	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER and INSTRUMENTATION & AUTOMATION	
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG284	DIGITAL LOGIC	4.0
EENG310	INFORMATION SYSTEMS SCIENCE I	3.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0

Courses

EENG198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG281. INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER. 3.0 Semester Hrs.
This course provides an engineering science analysis of electrical circuits. DC and single-phase AC networks are presented. Transient analysis of RC, RL, and RLC circuits is studied as is the analysis of circuits in sinusoidal steady-state using phasor concepts. The following topics are included: DC and single-phase AC circuit analysis, current and charge relationships. Ohm's Law, resistors, inductors, capacitors, equivalent resistance and impedance, Kirchhoff's Laws, Thevenin and Norton equivalent circuits, superposition and source transformation, power and energy, maximum power transfer, first order transient response, algebra of complex numbers, phasor representation, time domain and frequency domain concepts, and ideal transformers. The course features PSPICE, a commercial circuit analysis software package. May not also receive credit for EENG282. Prerequisite: PHGN200.

EENG282. ELECTRICAL CIRCUITS. 4.0 Semester Hrs.
This course provides an engineering science analysis of electrical circuits. DC and AC (single-phase and three-phase) networks are presented. Transient analysis of RC and RL circuits is studied as is the analysis of circuits in sinusoidal steady-state using phasor concepts. The following topics are included: DC and AC circuit analysis, current and charge relationships. Ohm's Law, resistors, inductors, capacitors,

equivalent resistance and impedance, Kirchhoff's Laws, Thevenin and Norton equivalent circuits, superposition and source transformation, power and energy, maximum power transfer, first order transient response, algebra of complex numbers, phasor representation, time domain and frequency domain concepts, and steady-state analysis of single-phase and three-phase ac power circuits. May not also receive credit for EENG281. 3 hours lecture; 3 hours lab; 4 semester hours. Prerequisite: PHGN200.

Course Learning Outcomes

- ABET outcomes A, B , E, G and K

EENG284. DIGITAL LOGIC. 4.0 Semester Hrs.

This course is an introduction to digital logic design. Students will start to learn how to design combinational logic circuit using Kmaps, manipulate these expressions using Boolean algebra and then produce basic building blocks like decoders and adders. Next students will focus on sequential logic circuits with basic memory elements, then design sequential building blocks like counters and registers and then to design finite state machines. Students will then learn how to combine basic building blocks with finite state machines to create complex functionality. Students will implement their design using a hardware description language and download these designs on FPGAs. Prerequisite: CSCI261 (C- or better) or CSCI200 (C- or better). Co-requisite: EENG282 or EENG281 or PHGN215.

Course Learning Outcomes

- Unchanged

EENG298. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG299. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG299. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG307. INTRODUCTION TO FEEDBACK CONTROL SYSTEMS. 3.0 Semester Hrs.

System modeling through an energy flow approach is presented, with examples from linear electrical, mechanical, fluid and/or thermal systems. Analysis of system response in both the time domain and frequency domain is discussed in detail. Feedback control design techniques, including PID, are analyzed using both analytical and computational methods. Prerequisite: EENG281 or EENG282 or PHGN215 (C- or better) and MATH225 or MATH235.

Course Learning Outcomes

- Unchanged

EENG310. INFORMATION SYSTEMS SCIENCE I. 3.0 Semester Hrs.

Equivalent with EENG388,

The interpretation, representation and analysis of time-varying phenomena as signals which convey information and noise; applications are drawn from filtering, audio and image processing, and communications. Topics include convolution, Fourier series and transforms, sampling and discrete-time processing of continuous-time signals, modulation, and z-transforms. Prerequisite: EENG281 or EENG282 or PHGN215 (C- or better), MATH225 or MATH235. Co-requisite: EENG 391.

Course Learning Outcomes

- Compute and interpret the spectrum of continuous and discrete-time signals
- Determine the effect of converting between continuous and discrete-time signals, and choose sampling rates using the guidelines of the Nyquist sampling theorem
- Determine the response of a discrete time system using convolution, z-transforms, or frequency response techniques
- Determine the response of a continuous time system using convolution, Fourier Transforms or frequency response techniques
- Use MATLAB to analyze and implement digital filters

EENG311. INFORMATION SYSTEMS SCIENCE II. 3.0 Semester Hrs.

This course covers signals and noise in electrical systems. Topics covered include information theory, signal to noise ratio, random variables, probability density functions, statistics, noise, matched filters, coding and entropy, power spectral density, and bit error rate. Applications are taken from radar, communications systems, and signal processing. Prerequisite: EENG310. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- 1. Students will learn how to characterize information and noise in electrical systems.
- 2. Students will be able to apply probability concepts, such as Bayes rule to electrical systems.
- 3. Students will be able to apply statistical concepts, such as construct a confidence interval for a parameter estimate to electrical systems.
- 4. Students will be able to compute the probability of detecting signals in noise.

EENG340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I,II,S) Supervised, full-time engineering- related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Engineering Division Faculty Co-op Advisor prior to enrolling to clarify the educational objectives for their individual Co-op program. 3 semester hours credit will be granted once toward degree requirements. Credit earned in EGGN340, Cooperative Education, may be used as free elective credit hours or a civil specialty elective if, in the judgment of the Co-op Advisor, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives or civil electives requires the student to submit a ?Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements? form obtained from the Career Center to the Engineering Division Faculty Co-op Advisor.

EENG350. SYSTEMS EXPLORATION AND ENGINEERING DESIGN LAB. 3.0 Semester Hrs.

This laboratory is a semester-long design and build activity centered around a challenge problem that varies from year to year. Solving this problem requires the design and prototyping of a complex system and utilizes concepts from multiple electrical engineering courses. Students work in intra-disciplinary teams to build modular sub-systems and integrate them to a complete system.

Course Learning Outcomes

- ABET outcome b, c, e, g, i and k

EENG383. EMBEDDED SYSTEMS. 4.0 Semester Hrs.

The design and implementation of systems consisting of analog and digital components with a microcontroller to perform a dedicated task. Student will implement systems using a variety of microcontroller subsystems including timers, PWM, ADC, serial communication subsystems and interrupts. Students will learn embedded systems programming techniques like, fixed-point math, direct digital synthesis, lookup tables, and row scanning. Student will program the microcontroller using a high-level programming language like C or C++. Prerequisite: EENG281 or EENG282 or PHGN215 (C-or better) and EENG284 or PHGN317 (C-or better).

Course Learning Outcomes

- Unchanged

EENG385. ELECTRONIC DEVICES AND CIRCUITS. 4.0 Semester Hrs.

Students will study the large signal and small signal behavior of active components including opamps, diodes, bipolar junction transistors, and field effect transistors. Students will explore the frequency response analysis of standard circuit configurations. Students will engage laboratory exercises to compare how well their theoretical analysis compare to the actual circuit. 3 hours lecture; 3 hours lab; 4 semester hours. Prerequisite: EENG307.

Course Learning Outcomes

- Unchanged

EENG386. FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS. 3.0 Semester Hrs.

This course introduces electromagnetic theorems leading to engineering applications related to antennas, wireless communications, and microwave devices. Maxwell's equations will be introduced and analyzed for static and time varying applications. They will also be used to describe electric and magnetic fields behavior in space and time and how they represent energy transmission and radiation. A review of vector calculus and coordinates systems will be conducted first as they are essential in understanding and manipulations of several electromagnetic theorems. 3 hours lecture; 3 semester hours. Prerequisite: EENG281 (C- or better) or EENG282 (C- or better), and MATH225 or MATH235.

Course Learning Outcomes

- Unchanged

EENG389. FUNDAMENTALS OF ELECTRIC MACHINERY. 4.0 Semester Hrs.

This course provides an engineering analysis of electrical machines. The following topics are included: review of three-phase AC circuit analysis, magnetic circuit concepts and materials, transformer analysis and operation, modelling, steady-state analysis of rotating machines, synchronous and poly-phase induction motors, and DC machines and laboratory study of external characteristics of machines and transformers. Prerequisite: EENG281 (C- or better) or EENG282 (C- or better). 3 hours lecture, 3 hours lab; 4 semester hours.

Course Learning Outcomes

- Unchanged

EENG390. ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID. 3.0 Semester Hrs.

(WI) Fundamentals and primary sources of energy; Energy conversion; Comprehensive energy picture in USA and the world; Generation of electric power today; Understanding of the electric power grid and how it works; Renewable energy resources and distributed generation; Wind and PV power generation; Future trend in electricity delivery; Energy sustainability. 3 hours lecture; 3 semester hours. Prerequisite: EENG281 or EENG282 or PHGN215.

Course Learning Outcomes

- ABET A-K

EENG391. FE ON COMPUTATIONAL METHODS FOR ELECTRICAL ENGINEERING. 1.0 Semester Hr.

Students will learn computational methods for common tasks in electrical engineering such as creating and plotting signals and data, analyzing and implementing digital filters, numerically computing integrals, solving differential equations, and simulating dynamical systems. Prerequisite: EENG281 or EENG282 or PHGN215 (C- or better), MATH225 or MATH235. Co-requisite: EENG310.

Course Learning Outcomes

- Create and plot signals and data using MATLAB
- Use MATLAB to analyze and implement digital filters
- Use MATLAB and Simulink for integration, differentiation, and simulation of dynamical systems

EENG392. FE ON INFORMATION AND SYSTEMS SCIENCES. 1.0 Semester Hr.

The course will present hardware and software solutions for the purpose of creating customized instrumentation and control systems. Concepts presented include 1) User Interface Design: controls, indicators, dialogs, graphs, charts, tab controls, user interface best practices 2) Software Development: basic software architecture, loops, arrays, binary logic, mathematics, data management 3) Instrumentation basics: connecting sensors to hardware, acquiring data, analyzing instrumentation accuracy, examining resolution and noise characteristics of a signal 4) Control basics: create pulse-width modulated (PWM) signals for controlling motors, servos, amplifiers, and heaters. Create a PID control algorithm to control a dynamic system. 1 hour lecture; 2 hours lab; 1 semester hour. Prerequisite: EENG281 or EENG282 and CSCI261 or CSCI200. Co-requisite: EENG307.

Course Learning Outcomes

- Students will be able to write and present a report that describes a contemporary product or process and how signal processing, control and/or instrumentation enables this product or process.
- Students will be able to utilize documentation and web resources develop signal processing, control and instrumentation applications using state of the art software and hardware
- Students will be able to describe the societal impact of current signal processing, control, instrumentation, and robotics applications.

EENG393. FE ON INTEGRATED CIRCUITS AND ELECTRONICS PRACTICUM. 1.0 Semester Hr.

Students will learn how to design, fabricate, and solder a printed circuit board (PCB) from concept to implementation. In addition to teaching best design practices, the course will address the variety of real-world constraints that impact the manufacturing of electrical circuits on PCBs. 1 hour lecture; 2 hours lab; 1 semester hour. Prerequisite: EENG383 or EENG385.

Course Learning Outcomes

- Students are expected to embrace the philosophy that in complex PCB design
- Making trade-offs between competing, and often conflicting, goals.

EENG394. FE ON ANTENNAS AND WIRELESS COMMUNICATIONS. 1.0 Semester Hr.
(I) This course provides the basic theories of electromagnetics, antennas, and wireless communications. Hands on experience will be developed during the projects assigned in the class to design antennas and passive microwave devices. 0.5 hours lecture; 1.5 hours lab; 1 semester hour.
Course Learning Outcomes

- 1) learn how to select different antennas to meet the design requirements and application
- 2) perform detailed design analysis in the context of electromagnetic simulation
- 3) establish and develop error analysis associated with the design through simulation
- 4) fabricate simple antennas and passive microwave devices
- 5) perform the basic measurements in an antenna lab
- 6) write a professionally acceptable technical report.

EENG395. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
(I, II) Individual research project for freshman, sophomores or juniors under direction of a member of the departmental faculty. Written report required for credit. Seniors should take EENG495 instead of EENG395. Repeatable for credit. Variable credit; 1 to 3 semester hours.
Course Learning Outcomes

- 1. Students will successfully complete a research project under direction of a member of the departmental faculty.

EENG398. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG411. DIGITAL SIGNAL PROCESSING. 3.0 Semester Hrs.
This course introduces the mathematical and engineering aspects of digital signal processing (DSP). An emphasis is placed on the various possible representations for discrete-time signals and systems (in the time, z-, and frequency domains) and how those representations can facilitate the identification of signal properties, the design of digital filters, and the sampling of continuous-time signals. Advanced topics include sigma-delta conversion techniques, multi-rate signal processing, and spectral analysis. The course will be useful to all students who are concerned with information bearing signals and signal processing in a wide variety of application settings, including sensing, instrumentation, control, communications, signal interpretation and diagnostics, and imaging. Prerequisite: EENG310. 3 hours lecture; 3 semester hours.

EENG413. ANALOG AND DIGITAL COMMUNICATION SYSTEMS. 4.0 Semester Hrs.
Signal classification; Fourier transform; filtering; sampling; signal representation; modulation; demodulation; applications to broadcast, data transmission, and instrumentation. Prerequisite: EENG310. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG415. DATA SCIENCE FOR ELECTRICAL ENGINEERING. 3.0 Semester Hrs.
This course presents a comprehensive exposition of the theory, methods, and algorithms for data analytics as related to power and energy systems. It will focus on (1) techniques for performing statistical inference based on data, (2) methods for predicting future values of data, (3) methods for classifying data instances into relevant classes and clusters, (4) methods for building, training and testing artificial neural networks, and (5) techniques for evaluating the effectiveness and quality of a data analytics model. Prerequisite: EENG311.
Course Learning Outcomes

- LO1: Describe sources and types of data in modern energy and automation systems
- LO2: Apply R commands to analyze data and develop data analytics models
- LO3: Apply statistical analysis tools to process raw data
- LO4: Derive statistical inferences about a population
- LO5: Assign data instances to classes
- LO6: Apply regression techniques to model the relationship among variables of interest
- LO7: Design artificial neural networks for various prediction applications
- LO8: Evaluate the performance of a developed model using appropriate metrics

EENG417. MODERN CONTROL DESIGN. 3.0 Semester Hrs.
Control system design with an emphasis on observer-based methods, from initial open-loop experiments to final implementation. The course begins with an overview of feedback control design technique from the frequency domain perspective, including sensitivity and fundamental limitations. State space realization theory is introduced, and system identification methods for parameter estimation are introduced. Computerbased methods for control system design are presented. Prerequisite: EENG307. 3 lecture hours, 3 semester hours.

EENG421. SEMICONDUCTOR DEVICE PHYSICS AND DESIGN. 3.0 Semester Hrs.
This course will explore the field of semiconductors and the technological breakthroughs which they have enabled. We will begin by investigating the physics of semiconductor materials, including a brief foray into quantum mechanics. Then, we will focus on understanding pn junctions in great detail, as this device will lead us to many others (bipolar transistors, LEDs, solar cells). We will explore these topics through a range of sources (textbooks, scientific literature, patents) and discuss the effects they have had on Western society. As time allows, we will conclude with topics of interest to the students (possibilities include quantum devices, MOSFETs, lasers, and integrated circuit fabrication techniques). Prerequisite: PHGN200. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Explain what a semiconductor is and how to change its properties (through doping, application of a voltage potential, etc.)
- Use a band diagram to explain how a pn junction diode works

- Describe how innovations in semiconductor devices (the integrated circuit, high efficiency white LEDs, improved solar cells) have changed our world (modern computing, energy efficiently lighting, alternative energy).
- Identify the idealities in device models and understand their limitations
- Apply the concepts learned in class to the design of novel devices or improvement of an existing device
- Characterize the difference between devices of the same “family” (BJTs vs. MOSFETS, lasers vs. LEDs vs. photovoltaics)
- Explain concepts to a broad audience through varied forms (written, multimedia, etc.)

EENG423. INTRODUCTION TO VLSI DESIGN. 3.0 Semester Hrs.
This is an introductory course that will cover basic theories and techniques of digital VLSI (Very Large Scale Integrated Circuits) design and CMOS technology. The objective of this course is to understand the theory and design of digital systems at the transistor level. The course will cover MOS transistor theory, CMOS processing technology, techniques to design fast digital circuits, techniques to design power efficient circuits, standard CMOS fabrications processes, CMOS design rules, and static and dynamic logic structures. Prerequisites: EENG281 (C- or better) or EENG282 (C- or better), and EENG284 (C- or better). 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Derive an ideal model for the MOSFET relating current and voltage
- Communicate effectively about the integrated circuit fabrication process
- Design transistor-level combinational and sequential circuits
- Predict the static and dynamic behavior of digital CMOS systems
- Perform a timing and power analysis on CMOS circuits

EENG425. INTRODUCTION TO ANTENNAS. 3.0 Semester Hrs.
This course provides an introduction to antennas and antenna arrays. Theoretical analysis and use of computer programs for antenna analysis and design will be presented. Experimental tests and demonstrations will also be conducted to complement the theoretical analysis. Students are expected to use MATLAB to model antennas and their performance. Prerequisites: EENG386.
Course Learning Outcomes

- 1. Characterize antenna by their basic properties, such as directivity, polarization, impedance, etc.
- 2. Calculate the properties of dipole and loop antennas.
- 3. Design linear and planar array antennas.
- 4. Characterize the radiation pattern of aperture antennas.
- 5. Design rectangular patch antennas.
- 6. Read an IEEE Antennas and Propagation Society publication and reproduce the results in MATLAB.
- 7. Design, build, and test a simple antenna that operates at 2 GHz.niques
- 8. Design, build, and test a direction finding array. and antenna arrays. This also includes the development of visualization files for the radiation patterns and the input impedance.

EENG427. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.
This course provides the tools needed to analyze and design a wireless system. Topics include link budgets, satellite communications, cellular communications, handsets, base stations, modulation techniques, RF propagation, coding, and diversity. Students are expected to complete an extensive final project. Prerequisite: EENG311 or MATH201 and EENG310.
Course Learning Outcomes

- 1. Calculate the link budget of a wireless communications system.
- 2. Estimate effects of wireless propagation mechanisms on signals.
- 3. Be able to apply statistical channel models to wireless channels.
- 4. Characterize antenna properties associated with wireless communications.
- 5. Describe, analyze, and understand engineering tradeoffs associated with modulation, coding, multiple access, and spread spectrum techniques.
- 6. Write a paper and present a project on an advanced wireless communications topic not covered in class.

EENG428. COMPUTATIONAL ELECTROMAGNETICS. 3.0 Semester Hrs.
This course provides the basic formulations and numerical solutions for static and full wave electromagnetic problems. Static problems are based on Laplace and Poisson equations while full wave electromagnetic problems are based on differential and integral forms of Maxwell?s equations. Different numerical methods will be introduced such as: finite difference, finite difference frequency domain, finite difference time domain, and method of moments. The numerical development and implementation of these methods using MATLAB will be conducted to solve practical problems. 3 hours lecture; 3 semester hours. 3 hours lecture; 3 semester hours. Prerequisite: EENG386.
Course Learning Outcomes

- 1. Learn how to work with differential and integral equations representing field quantities into a computational model.
- 2.Learn how to build and perfect the development of a computational model to solve electromagnetic problems
- 3.learn how to develop visualization tools and to validate the accuracy of generated numerical results

EENG430. PASSIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.
This course introduces the basics of passive radio-frequency (RF) and microwave circuits and devices which are the building blocks of modern communication and radar systems. The topics that will be studied are microwave transmission lines and waveguides, microwave network theory, microwave resonators, power dividers, directional couplers, hybrids, RF/microwave filters, and phase shifters. Students will also learn how to design and analyze passive microwave devices using professional CAD software. Moreover, students will learn how to fabricate printed passive microwave devices and test them using a vector network analyzer. Prerequisites: EENG386. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Learn how to analyze and design a variety of passive RF and microwave devices such as filters which will improve the students’ ability to identify, formulate, and solve engineering problems.
- 2. Understand the basic operation mechanism of multiport microwave networks systems which will improve the students’ ability to apply knowledge of mathematics, science, and engineering in a system level problem.
- 3. Learn how to use vector network analyzers and measure passive microwave devices which will improve the students’ ability to apply knowledge of mathematics, science, and engineering.

- 4. Learn how to model passive microwave circuits and devices using a professional CAD tool which will improve the students' ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

EENG433. ACTIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.
(II) This course introduces the basics of active radio-frequency (RF) and microwave circuits and devices which are the building blocks of modern communication and radar systems. The topics that will be studied are RF and microwave circuit components, resonant circuits, matching networks, noise in active circuits, switches, RF and microwave transistors and amplifiers. Additionally, mixers, oscillators, transceiver architectures, RF and monolithic microwave integrated circuits (RFICs and MMICs) will be introduced. Moreover, students will learn how to model active devices using professional CAD software, how to fabricate printed active microwave devices, how a vector network analyzer (VNA) operates, and how to measure active RF and microwave devices using VNAs. 3 hours lecture; 3 semester hours. Prerequisite: EENG385 and EENG429 or EENG529.
Course Learning Outcomes

- 1. Learn how to analyze and design a variety of active RF and microwave devices such as power amplifiers which will improve the students' ability to identify, formulate, and solve engineering problems.
- 2. Understand the basic operation mechanism of transmitters and receivers in communication systems which will improve the students' ability to apply knowledge of mathematics, science, and engineering in a system level problem
- 3. Gain a basic understanding on how vector network analyzers operate and how to measure active microwave devices which will improve the students' ability to apply knowledge of mathematics, science, and engineering
- 4. Learn how to model active microwave circuits and devices using a professional CAD tool which will improve the students' ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

EENG437. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.
Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. 3 hours lecture; 3 semester hours. Prerequisite: MATH201 or EENG311, MATH332, CSCI261 or CSCI200, Senior level standing.
Course Learning Outcomes

- 1. Be able to analyze and predict the behavior of image formation, transformation, and recognition algorithms.
- 2. Be able to design, develop, and evaluate algorithms for specific applications.
- 3. Be able to use software tools to implement computer vision algorithms.

EENG470. INTRODUCTION TO HIGH POWER ELECTRONICS. 3.0 Semester Hrs.
Power electronics are used in a broad range of applications from control of power flow on major transmission lines to control of motor speeds in industrial facilities and electric vehicles, to computer power supplies. This course introduces the basic principles of analysis and design of circuits utilizing power electronics, including AC/DC, AC/AC, DC/DC, and DC/AC conversions in their many configurations. 3 hours lecture; 3 semester hours. Prerequisite: EENG282, EENG389.
Course Learning Outcomes

- Unchanged

EENG475. INTERCONNECTION OF RENEWABLE ENERGY, INTEGRATED POWER ELECTRONICS, POWER SYSTEMS, AND POWER QUALITY. 3.0 Semester Hrs.
This course focuses on different aspects of interconnection of distributed renewable generation resources at the power distribution and transmission levels. Students will have a clear understanding of the source and electrical characteristics of different renewable energy sources and the challenges associated with the integration of renewable generation resources with the current power grid. Hands-on simulation-based case studies will help the students examine the covered topics on realistic power system models and understand how renewable energy interconnection issues affect power and voltage quality. Students will also be introduced to the US electricity markets and the role of renewable energy and energy storage in providing deliverable energy flexibility. The course consists of a mathematical and analytical understanding of relevant electrical energy conversion systems analysis and modeling issues. Prerequisite: EENG282, EENG389, EENG470.
Course Learning Outcomes

- UNIT #1 – Sources of Renewable Energy (eight modules) -- LO_1: Explain the role of renewable energy sources vs. traditional sources, in the supply of electrical power - Students will write summaries and comparisons
- UNIT #2 – Power Electronics and Poser Systems Conversion (four modules) -- LO_2: Identify the basic design components and their functions for the selected energy conversion devices. Students will work on computational modeling of components and devices.
- UNIT #3 – Energy Storage for Renewable Energy Systems (three modules) -- LO_3: Identify ways to store renewable energy, understand how to use energy storage principles to perform basic system design and component selection for the selected energy storage devices. Students will work on computational modeling of components and devices.
- UNIT #4 – Power Quality and Signal Processing for Grid-Connected versus Stand-Alone Renewable Energy Systems (two modules) -- LO_4: Students will write identification reports of power quality, voltage vs current quality. Students will work on algorithms for signal processing of power quality measurements and improvements. Students will work on implementing algorithms for analysis of power quality using Spreadsheet and/or Matlab scripts.
- UNIT #5 – Final Project Based Learning (two modules) -- LO_5: Whole case study using computational tools. Students will work in pairs, developing a common final project based learning. Students should use all their previous reports, presentations, algorithms, case studies to come-up with a final project. Students will have to use Physics, Mathematics and Engineering Analysis to develop their modeling and control strategies, implement in Matlab, Simulink, PSIM

and spreadsheet. Their Final Project will generate a Final Report, plus a Final Presentation.

EENG480. POWER SYSTEMS ANALYSIS. 3.0 Semester Hrs.
3-phase power systems, per-unit calculations, modeling and equivalent circuits of major components, voltage drop, fault calculations, symmetrical components and unsymmetrical faults, system grounding, power-flow, selection of major equipment, design of electric power distribution systems. Prerequisite: EENG389. 3 hours lecture; 3 semester hours.

EENG481. ANALYSIS AND DESIGN OF ADVANCED ENERGY SYSTEMS. 3.0 Semester Hrs.
The course investigates the design, operation and analysis of complex interconnected electric power grids, the basis of our electric power infrastructure. Evaluating the system operation, planning for the future expansion under deregulation and restructuring, ensuring system reliability, maintaining security, and developing systems that are safe to operate has become increasingly more difficult. Because of the complexity of the problems encountered, analysis and design procedures rely on the use of sophisticated power system simulation computer programs. The course features some commonly used commercial software packages. Prerequisite: EENG480.

EENG486. ELECTROMAGNETIC FIELDS AND WAVES. 3.0 Semester Hrs.
This course provides an introduction to electromagnetic fields and waves and their applications in antennas, radar, high-frequency electronics, and microwave devices. The time-varying form of electromagnetic fields and the use of sinusoidal time sources to create time-harmonic electromagnetic fields will be covered first, followed by coverage of plane electromagnetic waves formulation and reflection and transmission from different surfaces. Finally, the application of guided electromagnetic waves will be covered through the study of transmission lines, waveguides, and their applications in microwave systems. Prerequisite: EENG386. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Learn how to work with differential and integral forms of Maxwell's equations and plane electromagnetic waves and use them to design electromagnetic devices
- 2. Learn how to build electromagnetic models and use them to solve electromagnetic problems
- 3. Learn how to develop computer programs to visualize electromagnetic fields such as waveguide modes or signal propagation on transmission lines

EENG489. COMPUTATIONAL METHODS IN ENERGY SYSTEMS AND POWER ELECTRONICS. 3.0 Semester Hrs.
The course presents a unified approach for understanding and applying computational methods, computer-aided analysis and design of electric power systems. Applications will range from power electronics to power systems, power quality, and renewable energy. Focus will be on how these seemingly diverse applications all fit within the smart-grid paradigm. This course builds on background knowledge of electric circuits, control of dc/dc converters and inverters, energy conversion and power electronics by preparing students in applying the computational methods for multi-domain simulation of energy systems and power electronics engineering problems. Prerequisite: EENG282, EENG389, EENG470.

EENG495. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
(I, II) Individual research project under direction of a member of the departmental faculty. Written report required for credit. Prerequisites: senior-level standing based on credit hours. Variable credit; 1 to 3 semester hours. Repeatable for credit.

Course Learning Outcomes

- Students will successfully complete a research project under direction of a member of the departmental faculty.

EENG498. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Professor and Department Head

Peter Aaen

Professors

Atef Elsherbeni

Kathryn Johnson

Tyrone Vincent

Michael Wakin

Associate professors

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Abd Arkadan

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Teaching Assistant Professor

Hisham Sager

Emeriti Professor

Ravel Ammerman

Pankaj (PK) Sen

Jeffrey Schowalter

Marcelo Simoes

Emerita Professor

Catherine Skokan

Geology and Geological Engineering

Program Description

A Bachelor of Science degree in Geological Engineering is the basis for careers concentrating on the interaction of humans and the earth. Geological Engineers deal with a wide variety of the resource and environmental problems that come with accommodating more and more people on a finite planet. Geologic hazards and conditions must be recognized and considered in the location and design of foundations for buildings, roads, and other structures; waste disposal facilities must be properly located, designed, and constructed; contaminated sites and groundwater must be accurately characterized before cleanup can be accomplished; water supplies must be located, developed, and protected; and new mineral and energy resources must be located and developed in an environmentally sound manner. Geological Engineers are the professionals trained to meet these challenges.

The Geological Engineering curriculum provides a strong foundation in the basic sciences, mathematics, geological science, and basic engineering along with specialized upper-level instruction in integrated applications to real problems. Engineering design is integrated throughout the four-year program, beginning in Design I (Freshman year) and ending with the capstone design courses in the senior year.

The Bachelor of Science in Geological Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission’s General Criteria and Program Criteria for Geological and Similarly Named Engineering Programs.

Students have the background to take the Fundamentals of Engineering Exam, the first step in becoming a registered Professional Engineer.

Graduates follow five general career paths:

Engineering Geology and Geotechnics. Careers in site investigation, design and stabilization of foundations and slopes; site characterization, design, construction and remediation of waste disposal sites or contaminated sites; and assessment of geologic hazards for civil, mining or environmental engineering projects.

Groundwater Engineering. Careers in assessment and remediation of groundwater contamination, design of groundwater control facilities for geotechnical projects and exploration for and development of groundwater supplies.

Petroleum Exploration and Development Engineering. Careers in the search for and development of oil and gas and their efficient extraction.

Mineral Exploration and Development Engineering. Careers in the search for and development of natural deposits of metals, industrial materials and rock aggregate.

Geological Science. Students are also well prepared to pursue careers in basic geoscience. Graduates have become experts in fields as divergent as global climate change, the early history of the Earth, planetary science, fractal representation of groundwater flow, and simulation of sedimentary rock sequences, to name a few. Careers are available in research and education.

The curriculum may be followed along two concentration paths with slightly different upper-division requirements. Both concentrations are identical in the first two years as students study basic science, mathematics, engineering science, and geological science. In the junior year, those students pursuing careers in groundwater engineering, engineering geology and geotechnics, or geoenvironmental engineering applications follow the Environmental, Engineering Geology and Geotechnics, and Groundwater Engineering concentration. Students anticipating careers in resource exploration and development or who expect to pursue graduate studies in geological sciences follow the Mineral and Petroleum Exploration Engineering concentration.

At all levels the Geological Engineering Program emphasizes laboratory and field experience. All courses have a laboratory session, and after the junior year students participate in a field course, which is six weeks of geologic and engineering mapping and direct observation. The course involves considerable time outdoors in the mountains and canyons of Utah and southwestern Colorado.

At the senior level, students begin to focus on a career path by taking course sequences in at least two areas of geological engineering specialization. The course sequences begin with a 4-unit course in the fundamentals of a field of geological engineering which is followed by a 3-unit design-oriented course that emphasizes experience in direct application of principles through design projects.

Combined Undergraduate/Graduate Programs

Several degree programs offer CSM undergraduate students the opportunity to begin work on a graduate certificate, professional degree, or master's degree while completing the requirements for their bachelor's degree. These programs can give students a head start on graduate education. An overview of these combined programs and description of the admission process and requirements are found in the Graduate Degrees and Requirements section of the Graduate Catalog.

Program Educational Objectives (Bachelor of Science in Geological Engineering)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET accreditation criteria, the Geological Engineering program at CSM has established the following program educational objectives, which students are expected to attain within a few years of graduation:

1. Demonstrate a high level of technical competence
2. Demonstrate prowess in written, oral and graphical communication
3. Experience good teamwork and leadership practices

Student Learning Outcomes

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Program Requirements

In order to achieve the program goals listed above, every student working toward the Bachelor of Science Degree in Geological Engineering must complete the following requirements:

Degree Requirements (Geological Engineering)

Following the sophomore year, Geological Engineering students choose from one of two concentrations:

1. Minerals and Petroleum Exploration Engineering
2. Environmental, Engineering Geology and Geotechnics, and Ground-water Engineering

Minerals and Petroleum Exploration Engineering Concentration

Recommended for students intending careers in exploration and development of mineral and energy resources or intending careers in geoscience research and education.

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
PHGN100	PHYSICS I - MECHANICS			4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
HASS100	NATURE AND HUMAN VALUES			3.0
S&W	SUCCESS AND WELLNESS			1.0
				15.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
GEGN204	GEOLOGIC PRINCIPLES AND PROCESSES			3.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CEEN241	STATICS			3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
HASS200	GLOBAL STUDIES			3.0
				17.0
Spring		**lec**	**lab**	**sem.hrs**
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
CEEN311	MECHANICS OF MATERIALS			3.0
GEGN212	THE ROCK CYCLE			4.0
GEGN217	GEOLOGIC FIELD METHODS (GEOLOGIC FIELD METHODS)	1.0	8.0	2.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
				17.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
GEGN203	ENGINEERING TERRAIN ANALYSIS			3.0
GEOL309	STRUCTURAL GEOLOGY AND TECTONICS			4.0
GEOL321	MINERALOGY AND MINERAL CHARACTERIZATION			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
GEGN432	GEOLOGICAL DATA MANAGEMENT			3.0

		lec	lab	sem.hrs
GEGN307	PETROLOGY			4.0
GEOL314	STRATIGRAPHY	3.0	3.0	4.0
GEGN317	GEOLOGIC FIELD SKILLS (GEOLOGIC FIELD SKILLS)	1.0	4.0	1.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
				15.0
Summer		**lec**	**lab**	**sem.hrs**
GEGN316	FIELD GEOLOGY			5.0
				5.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
GEGN ELECT	GEGN4xx Option Elective			4.0
GEGN ELECT	GEGN4xx Option Elective			4.0
CEEN312	SOIL MECHANICS or MNGN 321 (RESTRICTED ELECTIVE)			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective	3.0		3.0
FREE	Free Elective			3.0
				17.0
Spring		**lec**	**lab**	**sem.hrs**
GEGN403	MINERAL EXPLORATION DESIGN			3.0
GEGN439	PETROLEUM EXPLORATION DESIGN			3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS			3.0
RESTRICTED ELECTIVE	Choose from list below.			3.0
FREE	Free Elective			3.0
				15.0

Total Semester Hrs: 133.0

* Technical Elective: MNGN321 or CEEN312.
Geologic Science and Engineering elective: An elective must be selected from a department list of approved courses. The elective must total 3 hours of math and basic sciences or engineering topics.

Restricted Elective List

GEGN	ANY 400 OR 500 LEVEL	
GEOL	ANY 400 OR 500 LEVEL	
GPGN	ANY 400 OR 500 LEVEL	
GEGN351	GEOLOGICAL FLUID MECHANICS	3.0
CEEN310	FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING	3.0
MEGN351	FLUID MECHANICS	3.0
CEEN415	FOUNDATION ENGINEERING	3.0

Option Electives

Student must take TWO of the following four courses:		8.0
GEGN401	MINERAL DEPOSITS	
GEGN438	PETROLEUM GEOLOGY	
GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN466L	GROUNDWATER ENGINEERING	1.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	

Design Electives

Students must take TWO of the following design courses, corresponding in subject area to the Option Elective:		6.0
GEGN403	MINERAL EXPLORATION DESIGN	
GEGN439	PETROLEUM EXPLORATION DESIGN	
GEGN469	ENGINEERING GEOLOGY DESIGN	
GEGN470	GROUND-WATER ENGINEERING DESIGN	

Environmental, Engineering Geology and Geotechnics, and GroundWater Engineering Concentration

Recommended for students intending careers in geotechnical engineering, hydrogeology, or other environmental engineering careers.

		lec	lab	sem.hrs
Freshman				
Fall		**lec**	**lab**	**sem.hrs**
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
PHGN100	PHYSICS I - MECHANICS			4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
HASS100	NATURE AND HUMAN VALUES			3.0
S&W	SUCCESS AND WELLNESS			1.0
				15.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
GEGN204	GEOLOGIC PRINCIPLES AND PROCESSES			3.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CEEN241	STATICS			3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
HASS200	GLOBAL STUDIES			3.0
				17.0
Spring		**lec**	**lab**	**sem.hrs**
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0

CEEN311	MECHANICS OF MATERIALS			3.0
GEGN212	THE ROCK CYCLE			4.0
GEGN217	GEOLOGIC FIELD METHODS			2.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
				17.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
MNGN321	INTRODUCTION TO ROCK MECHANICS			3.0
GEGN203	ENGINEERING TERRAIN ANALYSIS			3.0
GEOL309	STRUCTURAL GEOLOGY AND TECTONICS			4.0
EBGN201	PRINCIPLES OF ECONOMICS			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
				16.0

Spring		**lec**	**lab**	**sem.hrs**
CEEN312	SOIL MECHANICS			3.0
CEEN312L	SOIL MECHANICS LABORATORY			1.0
GEGN432	GEOLOGICAL DATA MANAGEMENT			3.0
GEOL314	STRATIGRAPHY			4.0
GEGN317	GEOLOGIC FIELD SKILLS			1.0
GEGN351	GEOLOGICAL FLUID MECHANICS			3.0
				15.0

Summer		**lec**	**lab**	**sem.hrs**
GEGN316	FIELD GEOLOGY			5.0
				5.0

Senior

Fall		**lec**	**lab**	**sem.hrs**
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	3.0	3.0	4.0
GEGN466	GROUNDWATER ENGINEERING			3.0
GEGN466L	GROUNDWATER ENGINEERING LABORATORY			1.0
GEGN473	GEOLOGICAL ENGINEERING SITE INVESTIGATION			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective	3.0		3.0
FREE	Free Elective	3.0		3.0
				17.0

Spring		**lec**	**lab**	**sem.hrs**
GEGN469	ENGINEERING GEOLOGY DESIGN			3.0
GEGN470	GROUND-WATER ENGINEERING DESIGN			3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS			3.0
FREE	Free Elective			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			
				12.0

Total Semester Hrs: 130.0

Students in the Environmental, Engineering Geology and Geotechnics, and Groundwater Engineering concentration may further specialize by utilizing their free elective courses to emphasize a specific specialty. Suggested courses are presented below and should be selected in consultation with the student's advisor. The emphasis area is an informal designation only and it will not appear on the transcript.

Engineering Geology and Geotechnics Emphasis

CEEN415	FOUNDATION ENGINEERING	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
GEGN399	INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY	1-6
GEGN499	INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY	1-6
GEGN307	PETROLOGY	4.0
GEOL321	MINERALOGY AND MINERAL CHARACTERIZATION	3.0
CSCI261	PROGRAMMING CONCEPTS	3.0
MNGN404	TUNNELING	3.0
MNGN408	UNDERGROUND DESIGN AND CONSTRUCTION	2.0
MNGN410	EXCAVATION PROJECT MANAGEMENT	2.0
MNGN445/545	ROCK SLOPE ENGINEERING	3.0

Water Engineering Emphasis

CEEN301	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: WATER	3.0
CEEN302	FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING: AIR AND WASTE MANAGEMENT	3.0
CEEN461	FUNDAMENTALS OF ECOLOGY	3.0
CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES	3.0
CEEN471	WATER AND WASTEWATER TREATMENT SYSTEMS ANALYSIS AND DESIGN	3.0
CEEN475	SITE REMEDIATION ENGINEERING	3.0
CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	3.0
CSCI261	PROGRAMMING CONCEPTS	3.0
CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0
CEEN492	ENVIRONMENTAL LAW	3.0
GEGN481	ANALYTICAL HYDROLOGY	3.0

GEGN483	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
GEGN499	INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY	1-6
GEOL321	MINERALOGY AND MINERAL CHARACTERIZATION	3.0
HASS487	ENVIRONMENTAL POLITICS AND POLICY	3.0
HASS488	GLOBAL WATER POLITICS AND POLICY	3.0
MATH332	LINEAR ALGEBRA	3.0
MEGN451	AERODYNAMICS	3.0

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- GEGN100 through GEGN599 inclusive
- GEGX100 through GEGX599 inclusive
- GEOC100 through GEOC599 inclusive
- GEOL100 through GEOL599 inclusive

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Geological Engineering Minor and Area of Special Interest

To receive a minor or ASI, a student must take at least 12 (ASI) or 18 (minor) credits of a logical sequence of courses. This may include GEGN101 (4 credits) and up to 4 credits at the 200-level.

Students must consult with the department to have their sequence of courses approved before embarking on a minor program.

Courses

GEGN101. EARTH AND ENVIRONMENTAL SYSTEMS. 4.0 Semester Hrs.
Equivalent with SYGN101,
(I, II, S) Fundamental concepts concerning the nature, composition and evolution of the lithosphere, hydrosphere, atmosphere and biosphere of the earth integrating the basic sciences of chemistry, physics, biology and mathematics. Understanding of anthropological interactions with the natural systems, and related discussions on cycling of energy and mass, global warming, natural hazards, land use, mitigation of environmental problems such as toxic waste disposal, exploitation and conservation of energy, mineral and agricultural resources, proper use of water resources, biodiversity and construction. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN203. ENGINEERING TERRAIN ANALYSIS. 3.0 Semester Hrs.
Geomorphology of landscapes and the physical processes that shape them. Landform morphology, evolution and complex connections to climatic, tectonic, geologic, biotic, anthropogenic and geomorphic processes. Theoretical and practical introduction to weathering, hillslopes, drainage systems, rivers and glaciers. Collection, analysis and interpretation of geomorphic data and maps. Applications of geomorphic information to solve geological engineering problems with emphasis on ethical and environmental considerations. Course will include fieldwork in Colorado, with analysis of landforms and geomorphic processes. 2 hours lecture, 3 hours lab; 3 semester hours. Prerequisite: GEGN101, MATH111.

GEGN204. GEOLOGIC PRINCIPLES AND PROCESSES. 3.0 Semester Hrs.
Processes and deposits on the Earth and other Celestial bodies that shape the worlds around us. Formation of the Earth and our Solar System. Evolution of the Earth as we know it today including the continents, oceans and processes that form and mold the natural world. Scientific methods for how we learn about our worlds Examination of the influences on energy and mineral resource development and distribution, as well as the impact of extraction and utilization in the built world. Collection and analysis of data from modern systems and application to understanding ancient systems imaged in seismic, geophysical borehole, and reflected in the occurrence of ancient fauna and flora. Data collection and application for assessing risk and solving geologic questions of past world and future environmental and engineering challenges. Course will include in-class exercises in interpretation of ancient landscapes, seascapes and deposits utilizing a variety of different types of data. Prerequisite: GEGN101.

GEGN212. THE ROCK CYCLE. 4.0 Semester Hrs.
Introduction to Earth materials. This course will teach foundations of mineralogy and petrology in lecture, including an introduction to crystal chemistry and mineral classification schemes and the concepts of rock forming processes as a basis for rock classification. Students will be able to link chemistry, mineralogy, and tectonic processes to rock forming processes and the associated rock classification. The associated laboratory will focus on practical skills used to identify minerals and rocks in hand sample. Prerequisite: CHGN122 or CHGN125. Co-requisite: GEGN217.
Course Learning Outcomes

- Students will be able to: 1. Analyze physical properties of minerals for identification and recall chemical information based on mineral ID.
- Students will be able to: 2. Classify minerals based on crystallographic structures and relate mineral structure to physical properties.
- Students will be able to: 3. Describe igneous, metamorphic, and sedimentary rocks and classify them according to standard classification schemes.
- Students will be able to: 4. Construct conceptual models of tectonic environments and compare temperature and pressure gradients between different environments.

- Students will be able to: 5. Relate rock composition and texture to tectonic environments and construct rock history from observations.

GEGN217. GEOLOGIC FIELD METHODS. 2.0 Semester Hrs.
Methods and techniques of geologic field observations and interpretations. Lectures in field techniques and local geology. Laboratory and field project in diverse sedimentary, igneous, metamorphic, structural, and surficial terrains using aerial photographs and topographic maps. Geologic cross sections, maps, and reports. Weekend exercises required. Prerequisite: GEGN101.
Course Learning Outcomes

- Students will be able to: 1. Systematically describe sedimentary, igneous and metamorphic rocks in the field
- Students will be able to: 2. Read and interpret topographic maps and construct topographic profiles
- Students will be able to: 3. Measure and record structural data and plot data on a map
- Students will be able to: 4. Interpret the nature of geological contacts in the field (conformable, unconformable, fault and intrusive contacts) and map locations on a base map
- Students will be able to: 5. Construct 1:1 scale geological cross sections
- Students will be able to: 6. Interpret geological histories from geological maps and cross sections

GEGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN299. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN307. PETROLOGY. 4.0 Semester Hrs.
Equivalent with GEOL307,
An introduction to igneous, sedimentary and metamorphic processes, stressing the application of chemical and physical mechanisms to study the origin, occurrence, and association of rock types. Emphasis on the megascopic and microscopic classification, description, and interpretation of rocks. Analysis of the fabric and physical properties. Prerequisite: GEOL321.
Course Learning Outcomes

- No change

GEGN316. FIELD GEOLOGY. 5.0 Semester Hrs.
Six weeks of field work, stressing geology of the Southern Rocky Mountain Province. Mapping of igneous, metamorphic, and sedimentary terrain using air photos, topographic maps, and other methods. Diversified individual problems in petroleum geology, mining geology, engineering geology, structural geology, and stratigraphy. Formal reports submitted on several problems. Frequent evening lectures and discussion sessions. Field trips emphasize regional geology as well as mining, petroleum, and engineering projects. Prerequisite: GEGN203, GEGN204, GEGN212 or GEOL314, GEGN317.
Course Learning Outcomes

- No changes

GEGN317. GEOLOGIC FIELD SKILLS. 1.0 Semester Hr.
Advanced methods and techniques of geologic field observations and interpretations. Field mapping projects in diverse sedimentary, igneous, metamorphic, structural, and surficial terrains using aerial photographs and topographic maps. Geologic cross sections, maps, and reports. Weekend exercises required. Course includes an introduction to camping skills and working in remote field locations. Prerequisite: GEGN217, GEGN212, GEOL309. Co-requisite: GEOL314.
Course Learning Outcomes

- Students will be able to: 1. Describe, name and interpret sedimentary, igneous and metamorphic rocks in the field and use their interpretations to develop geological models.
- Students will be able to: 2. Measure and record complex structural data and plot data both on a map and stereonet. Use a stereonet to interpret structural domains and kinematics.
- Students will be able to: 3. Interpret complex geological contacts and juxtapositions in the field and map these contacts carefully and accurately on a base map.
- Students will be able to: 4. Construct 1:1 scale geological cross sections of deformed terrains from map and notebook data.
- Students will be able to: 5. Interpret geological histories from geological maps and cross sections and relate these interpretations to regional tectonic processes.

GEGN330. GEOSCIENTISTS THERMODYNAMICS. 3.0 Semester Hrs.
Introduction to fundamental principles of thermodynamics applied to geosciences and geoengineering. Thermodynamics are used as a tool for evaluating the stability and chemical transformation of minerals and rocks, evolution of vapors and liquids and their reaction paths when subjected to different P-T geological regimes. The course will focus on basic principles of thermodynamics and make use of examples relevant to geoscientists encompassing: i) calculation of thermodynamic properties (volume, heat capacity, enthalpy and entropy) as a function of pressure, temperature and composition, ii) the study of heat transfer and volume change associated to chemical reactions and iii) evaluation of phase stabilities using Gibbs energy minimization and law of mass action. Introduction to pure phase properties, ideal and non-ideal solutions, activities, equilibrium constants, chemical potential, electrolytes, phase rule and Gibbs energy function. May not also receive credit for CHGN209 or CBEN210. Prerequisite: CHGN121, CHGN122 or CHGN125, MATH111, MATH112.
Course Learning Outcomes

- - Introduce basic principles of thermodynamics and their application to geological systems.
- - Predict the stability of minerals, liquids and vapors as a function of pressure and temperature.
- - Link thermodynamic predictions and basic principles with geological processes.
- - Learn to use the GEM-selektor software for calculation of thermodynamic properties as a function of pressure and temperature.

GEGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00.

1 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions. Repeatable.

GEGN342. ENGINEERING GEOMORPHOLOGY. 3.0 Semester Hrs.
Study of interrelationships between internal and external earth processes, geologic materials, time, and resulting landforms on the Earth's surface. Influences of geomorphic processes on design of natural resource exploration programs and siting and design of geotechnical and geohydrologic projects. Laboratory analysis of geomorphic and geologic features utilizing maps, photo interpretation and field observations. 2 hours lecture, 3 hours lab; 3 semester hours. Prerequisite: GEGN101.

GEGN351. GEOLOGICAL FLUID MECHANICS. 3.0 Semester Hrs.
Properties of fluids; Bernoulli's energy equation, the momentum and mass equations; laminar and turbulent flow in pipes, channels, machinery, and earth materials; subcritical and supercritical flow in channels; Darcy's Law; the Coriolis effect and geostrophic flow in the oceans and atmosphere; sediment transport. 3 hours lecture; 3 semester hours. Prerequisite: CEEN241.

GEGN398. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN399. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN401. MINERAL DEPOSITS. 4.0 Semester Hrs.
Introductory presentation of magmatic, hydrothermal, and sedimentary metallic ore deposits. Chemical, petrologic, structural, and sedimentological processes that contribute to ore formation. Description of classic deposits representing individual deposit types. Review of exploration sequences. Laboratory consists of hand specimen study of host rock-ore mineral suites and mineral deposit evaluation problems. Prerequisite: GEGN307, GEGN316.
Course Learning Outcomes

- Understand what economic geologists do (exploration and mining geologists)
- Understand the interface between geology and mining engineering, metallurgy, and environmental science) .
- Understand the basic types of metallic mineral deposits through lectures, readings, and laboratory examination of samples.
- Enhance student’s reading and writing skills.
- Enhance student’s ability to solve mineral exploration problems utilizing geologic maps and cross sections.

GEGN403. MINERAL EXPLORATION DESIGN. 3.0 Semester Hrs.
(WI) Exploration project design: commodity selection, target selection, genetic models, alternative exploration approaches and associated costs, exploration models, property acquisition, and preliminary economic evaluation. Lectures and laboratory exercises to simulate the entire exploration sequence from inception and planning through implementation to discovery, with initial ore reserve calculations and preliminary economic evaluation. Prerequisite: GEGN401, GEGN475 (or concurrent enrollment).

Course Learning Outcomes

- Sme

GEGN404. ORE MICROSCOPY. 3.0 Semester Hrs.
Identification of ore minerals using reflected light microscopy, micro-hardness, and reflectivity techniques. Interpretation of common ore mineral textures, including those produced by magmatic segregation, open space filling, replacement, exsolution, and recrystallization. Guided research on the ore mineralogy and ore textures of classical ore deposits. Prerequisite: GEOL321, GEGN401. 6 hours lab; 3 semester hours.

GEGN432. GEOLOGICAL DATA MANAGEMENT. 3.0 Semester Hrs.
(I, II, S) Techniques for managing and analyzing geological data, including statistical analysis procedures and computer programming. Topics addressed include elementary probability, populations and distributions, estimation, hypothesis testing, analysis of data sequences, mapping, sampling and sample representativity, linear regression, and overview of univariate and multivariate statistical methods. Practical experience with principles of software programming and statistical analysis for geological applications via suppled software and data sets from geological case histories. Prerequisites: Junior standing in Geological Engineering. 2 hours lecture; 3 hours lab; 3 semester hours.
Course Learning Outcomes

- 1. This course is intended to produce “computationally and statistically literate” geological engineers.
- 2. It combines experiences in computer programming with basic statistical methods useful to geologists and geological engineers.
- 3. Students will be exposed to “hands-on” data analysis and management issues with data sets representing various areas of geological study.

GEGN438. PETROLEUM GEOLOGY. 4.0 Semester Hrs.
Source rocks, reservoir rocks, types of traps, temperature and pressure conditions of the reservoir, theories of origin and accumulation of petroleum, geology of major petroleum fields and provinces of the world, and methods of exploration for petroleum. Term report required. Laboratory consists of study of well log analysis, stratigraphic correlation, production mapping, hydrodynamics and exploration exercises. Prerequisite: GEOL308 or GEOL309 and GEOL314 or GEOL315; and GEGN316 or GPGN486 or PEGN316. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN439. PETROLEUM EXPLORATION DESIGN. 3.0 Semester Hrs.
Equivalent with PEGN439,
(WI) This is a multi-disciplinary design course that integrates fundamentals and design concepts in geology, geophysics, and petroleum exploration. Students work both individually and in teams on multiple open-ended design problems in oil and gas exploration, including integration of well and seismic reflection databases, seismic interpretation in different tectonostratigraphic settings, and the development of a prospects in a variety of exploration plays. Several detailed written and oral presentations are made throughout the semester. 2 hours lecture, 3 hours lab; 3 semester hours. Prerequisite: GEOL309, GEOL314, GEGN438.
Course Learning Outcomes

- Make internally consistent interpretations of a complex 3D dataset.
- Develop a strong skill set in seismic interpretation using Petrel.
- Develop integrated geological (structural and stratigraphic) interpretations of 3D seismic data.

- Integrate geological interpretations with geophysics and petroleum engineering sections in a design project to assess the petroleum potential of an area through presentations and reports.

GEGN466. GROUNDWATER ENGINEERING. 3.0 Semester Hrs.
Theory of groundwater occurrence and flow. Relation of groundwater to surface water; hydraulic head distribution and flow; theory of aquifer tests; water chemistry, water quality, and contaminant transport. Prerequisites:MATH213 or MATH223, MATH225 or MATH235.
Course Learning Outcomes

- No changes to current class outcomes

GEGN466L. GROUNDWATER ENGINEERING. 1.0 Semester Hr.
Laboratory and field methods for groundwater hydrology, including groundwater occurrence and flow and contaminant transport. Prerequisite: MATH213 or MATH223, MATH225 or MATH235. Co-requisite: GEGN466.

GEGN468. ENGINEERING GEOLOGY AND GEOTECHNICS. 4.0 Semester Hrs.
Application of geology to evaluation of construction, mining, and environmental projects such as dams, water ways, tunnels, highways, bridges, buildings, mine design, and land-based waste disposal facilities. Design projects including field, laboratory, and computer analysis are an important part of the course. Prerequisite: MNGN321 and CEEN312/CEEN312L. 3 hours lecture, 3 hours lab, 4 semester hours.

GEGN469. ENGINEERING GEOLOGY DESIGN. 3.0 Semester Hrs.
(WI) This is a capstone design course that emphasizes realistic engineering geologic/geotechnics projects. Lecture time is used to introduce projects and discussions of methods and procedures for project work. Several major projects will be assigned and one to two field trips will be required. Students work as individual investigators and in teams. Final written design reports and oral presentations are required. 2 hours lecture, 3 hours lab; 3 semester hours. Prerequisite: GEGN468.

GEGN470. GROUND-WATER ENGINEERING DESIGN. 3.0 Semester Hrs.
(WI) Application of the principles of hydrogeology and ground-water engineering to water supply, geotechnical, or water quality problems involving the design of well fields, drilling programs, and/or pump tests. Engineering reports, complete with specifications, analysis, and results, will be required. 2 hours lecture, 3 hours lab; 3 semester hours. Prerequisite: GEGN 466 and 466L or equivalent, and GEGN351 or CEEN 310 or MEGN 351.
Course Learning Outcomes

- No change

GEGN473. GEOLOGICAL ENGINEERING SITE INVESTIGATION. 3.0 Semester Hrs.
Methods of field investigation, testing, and monitoring for geotechnical and hazardous waste sites, including: drilling and sampling methods, sample logging, field testing methods, instrumentation, trench logging, foundation inspection, engineering stratigraphic column and engineering soils map construction. Projects will include technical writing for investigations (reports, memos, proposals, workplans). Class will culminate in practice conducting simulated investigations (using a computer simulator).
Course Learning Outcomes

- No changes

GEGN475. APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS. 3.0 Semester Hrs.
An introduction to Geographic Information Systems (GIS) and their applications to all areas of geology and geological engineering. Lecture topics include: principles of GIS, data structures, digital elevation models, data input and verification, data analysis and spatial modeling, data quality and error propagation, methods of GIS projects, as well as video presentations. Prerequisite: GEGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN481. ANALYTICAL HYDROLOGY. 3.0 Semester Hrs.
Equivalent with GEGN581,
Introduction to the theory, and hydrological application of, probability, statistics, linear algebra, differential equations, numerical analysis, and integral transforms. Prerequisites: GEGN466. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- To introduce the student to the analysis of many types of hydrologic data using the tools from several mathematics courses, including basic probability and statistics, linear algebra, differential equations, and numerical. The course is also designed to develop the analytic skills necessary to understand and quantify hydrologic processes and problems.
- The class is designed to meet the Hydrologic Science and Engineering admission prerequisite of one semester each of Differential Equations and Probability/ Statistics.

GEGN483. MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS. 3.0 Semester Hrs.
Lectures, assigned readings, and direct computer experience concerning the fundamentals and applications of analytical and finite-difference solutions to ground water flow problems as well as an introduction to inverse modeling. Design of computer models to solve ground water problems. Prerequisites: Familiarity with computers, mathematics through differential and integral calculus, and GEGN466. 3 hours lecture; 3 semester hours.

GEGN498. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN499. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOC407. ATMOSPHERE, WEATHER AND CLIMATE. 3.0 Semester Hrs.
(II) An introduction to the Earth?s atmosphere and its role in weather patterns and long term climate. Provides basic understanding of origin and evolution of the atmosphere, Earth?s heat budget, global atmospheric circulation and modern climatic zones. Long- and short-term climate change including paleoclimatology, the causes of glacial periods and global warming, and the depletion of the ozone layer. Causes and effects of volcanic eruptions on climate, El Nino, acid rain, severe thunderstorms, tornadoes, hurricanes, and avalanches are also discussed. Microclimates and weather patterns common in Colorado.

Prerequisite: Completion of CSM freshman technical core, or equivalent. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOC408. INTRODUCTION TO OCEANOGRAPHY. 3.0 Semester Hrs.
(II) An introduction to the scientific study of the oceans, including chemistry, physics, geology, biology, geophysics, and mineral resources of the marine environment. Lectures from pertinent disciplines are included. Recommended background: basic college courses in chemistry, geology, mathematics, and physics. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL102. INTRODUCTION TO GEOLOGICAL ENGINEERING. 1.0 Semester Hr.
Presentations by faculty members and outside professionals of case studies to provide a comprehensive overview of the fields of Geology and Geological Engineering and the preparation necessary to pursue careers in those fields. A short paper on an academic professional path will be required. 1 hour lecture; 1 semester hour. Prerequisite: GEGN101 or concurrent enrollment.

GEOL198. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL199. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL308. INTRODUCTORY APPLIED STRUCTURAL GEOLOGY. 3.0 Semester Hrs.
Nature and origin of structural features of Earth's crust emphasizing structural controls on oil and gas entrapment. Structural patterns and associations are discussed in context of plate tectonic theories, using examples from across the globe. In class exercises and field projects in structural geometry, mapping and cross section construction and seismic reflection data interpretation. Course required of all PEGN students. Prerequisite: GEGN101.
Course Learning Outcomes

- • Apply the tools and methods of structural analysis, which are the basis for structural seismic interpretation and structural analysis of reservoirs.
- • Evaluate approaches and conclusions reached in geologic studies applied to petroleum and geophysical engineering projects.

GEOL309. STRUCTURAL GEOLOGY AND TECTONICS. 4.0 Semester Hrs.
(WI) Recognition, habitat, and origin of deformational structures related to stresses and strains (rock mechanics and microstructures) and plate tectonics. Structural development of mountain belts, rift, strike-slip and salt systems. Comprehensive field and laboratory projects use descriptive geometry, stereographic projection, structural contours, map and cross section construction, air photo interpretation, and seismic reflection data analysis. Required of Geological Engineers. 3 hours lecture, 3 hours lab; 4 semester hours. Prerequisite: GEGN204, GEGN217.
Course Learning Outcomes

- No change

GEOL310. EARTH MATERIALS. 3.0 Semester Hrs.
Introduction to Earth Materials, emphasizing the structure, formation, distribution and engineering behavior of minerals and rocks. Structural features and processes are related to stress/strain theory and rock mechanics principles. Laboratories and field exercises emphasize the recognition, description and engineering evaluation of natural materials. Lectures and case study exercises present the knowledge of natural materials and processes necessary for mining engineering careers. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: GEGN101.
Course Learning Outcomes

- see attached document

GEOL311. MINING GEOLOGY. 3.0 Semester Hrs.
Introduction to Mining Geology, emphasizing the formation, distribution, engineering behavior, exploration for and geological aspects of development of ore materials. Laboratories emphasize the recognition, description and engineering evaluation of ores and their hosts. Lectures and case study exercises present the knowledge of ores and ore-forming processes necessary for mining engineering careers. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: GEGN101 and GEOL310 or MNGN310.
Course Learning Outcomes

- see attached document

GEOL314. STRATIGRAPHY. 4.0 Semester Hrs.
Lectures and laboratory and field exercises in concepts of stratigraphy and biostratigraphy, facies associations in various depositional environments, sedimentary rock sequences and geometries in sedimentary basins, and geohistory analysis of sedimentary basins. 3 hours lecture, 3 hours lab; 4 semester hours. Prerequisite: GEGN101, GEGN212, GEGN217.
Course Learning Outcomes

- Understanding stratigraphy, biostratigraphy, facies associations, sedimentary rock sequences, and sedimentary basins.

GEOL315. SEDIMENTOLOGY AND STRATIGRAPHY. 3.0 Semester Hrs.
Integrated lecture, laboratory and field exercises on the genesis of sedimentary rocks as related to subsurface porosity and permeability development and distribution for non-geology majors. Emphasis is placed on siliciclastic systems of varying degrees of heterogeneity. Topics include diagenesis, facies analysis, correlation techniques, and sequence and seismic stratigraphy. Application to hydrocarbon exploitation stressed throughout the course. Required of all PEGN students. Prerequisite: GEGN101, PEGN308. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL321. MINERALOGY AND MINERAL CHARACTERIZATION. 3.0 Semester Hrs.
Principles of mineralogy and mineral characterization. Crystallography of naturally occurring materials. Principles of crystal chemistry. Interrelationships among mineral structure, external shape, chemical composition, and physical properties. Introduction to mineral stability. Laboratories emphasize analytical methods, including X-ray diffraction, scanning electron microscopy, and optical microscopy. 2 hours lecture,

3 hours lab: 3 semester hours. Prerequisite: GEGN101, GEGN212, CHGN122 or CHGN125.
Course Learning Outcomes

- No change

GEOL398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

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(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL410. PLANETARY GEOLOGY. 3.0 Semester Hrs.
Introduction to the geology of planets, moons, and other bodies within and beyond our solar system. Focusing on topics such as (a) the origin and composition of our solar system and its constituent materials, (b) geologic processes occurring on planetary surfaces (e.g. cratering) and shallow and deep interiors (e.g. volcanism, mantle convection), (c) methods of solar system exploration, and potential for resource discovery and utilization on near-neighbors and asteroids, and (d) comparative planetology (thermal histories, evidence for plate tectonics, origin and retention of atmospheres, exobiology).
Course Learning Outcomes

- Students will learn geological processes of the solar system.

GEOL440. PLATE TECTONICS. 3.0 Semester Hrs.
Introduction to the theory of plate tectonics as a first-order framework with which the evolution of the Earth?s lithosphere in space and time may be described and understood. Key topics include plate boundaries, the mechanisms of mountain building, crustal growth and destruction, volcanism and seismicity in intraplate and plate-margin settings, and secular changes in plate tectonic processes and products over geological time. Formation of all rock types (igneous, sedimentary, metamorphic) will be discussed in the context of plate tectonics. Other planets and planetary processes will be discussed and compared to Earth. Prerequisite: Basic geology knowledge; Consent from instructor.
Course Learning Outcomes

GEOL443. UNDERGRADUATE FIELD SEMINAR. 1-3 Semester Hr.
Special advanced classroom and field programs emphasizing detailed study of some aspects of the geology of an area or region. Field studies normally conducted away from the Golden campus. Classroom course content dependent on area of study. Fees assessed for field and living expenses and transportation. 1 to 3 semester hours; may be repeated for credit.

GEOL444. INVERTEBRATE PALEONTOLOGY. 3.0 Semester Hrs.
Fossils are the basis for establishing global correlation among Phanerozoic sedimentary rocks, and thus are critical to the reconstruction of the past 550 million years of Earth history. This is a lecture elective course that will aid in rounding out undergraduate Earth science/ engineering geological knowledge. Fossil preservation, taphonomy, evolution, mass extinctions, biostratigraphy, graphic correlation, invertebrate phyla and their geologic history and evolution. Prerequisites: GEGN203, GEGN204. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- At the conclusion of the class students will be able to... Recognize the characteristics of the major phyla and classes of invertebrate fossils/ animals; Explain how fossils are used in establishing geologic age of rocks and correlation; Explain how a fossil species is recognized, formally described, and classified into higher taxonomic categories; Explain the components of current evolutionary theory and how the fossil record supports it. These relate to the desired outcome of students being scientifically curious and to feeding their wonder over the beauty and complexity of the natural world.

GEOL470. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.
Students are introduced to geoscience applications of satellite remote sensing. Introductory lectures provide background on satellites, sensors, methodology, and diverse applications. One or more areas of application are presented from a systems perspective. Guest lecturers from academia, industry, and government agencies present case studies focusing on applications, which vary from semester to semester. Students do independent term projects, under the supervision of a faculty member or guest lecturer, that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 3 hours lecture; 3 semester hours.

GEOL498. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL499. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Professor and Department Head

Wendy A. Bohrson

Professors

David A. Benson

Zhaoshan Chang, Charles F. Fogarty Endowed Chair

Thomas Monecke, Director of Center for Advanced Subsurface Earth Resource Models and Co-Director of Center for Mineral Resources Science

Alexis Navarre-Sitchler, Joint Faculty Appointee, Energy and Natural Resources Security Group Los Alamos National Laboratory

Piret Plink-Bjorklund

Eric Roberts, Director, Potential Gas Agency

Paul M. Santi, Director of Center for Mining Sustainability

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Gabriel Walton

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Samuel B. Romberger

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Timothy A. Cross

Gregory S. Holden

Geophysics

Program Description

Founded in 1926, the Department of Geophysics at Colorado School of Mines is recognized and respected around the world for its programs in applied geophysical research and education. Geophysics is a multidisciplinary field that blends geology, physics, mathematics, computer science, and electrical engineering. Professionals working in geophysics often come with training from programs in these allied disciplines, as well as from formal programs in geophysics.

Geophysicists study and explore the interior of the Earth (and other planetary bodies) through physical measurements collected at its surface and in the subsurface, as well as remotely via airborne and satellite platforms. Using a combination of mathematical analyses based on data collected using a multitude of sensitive sensors, and insight into physical and chemical processes cast in the relevant geological contexts, geophysicists reveal the detailed structure of the Earth’s interior and explain a multitude of societally relevant natural processes. Noninvasive imaging beneath the surface of geologic bodies by geophysicists is directly analogous to noninvasive imaging of the human body by medical specialists.

Earth supplies all the materials needed by our society, serves as the repository of used products, and provides a home to all its inhabitants. Geophysicists and geophysical engineers have important roles to play in solving challenging problems facing the inhabitants of the Earth, such as providing fresh water, food, and energy for its growing population, evaluating sites for underground construction and containment of hazardous waste, noninvasive monitoring of aging infrastructure (water and telecommunication conduits, transportation networks), mitigating the threat of geohazards to populated areas (earthquakes, volcanoes, landslides, avalanches), aid homeland security (through detection of underground activity and removal of unexploded ordnance or land mines), evaluating changes in climate and managing humankind's response to them, as well as satisfying the human thirst for knowledge by exploring Earth and other planetary bodies.

Energy and mineral companies employ geophysicists to explore subsurface resources worldwide. Engineering firms hire geophysical engineers to assess Earth's near-surface properties for large construction and infrastructure projects. Environmental organizations rely on geophysics to conduct groundwater surveys and to track the flow, distribution, and concentration of contaminants. Geophysicists employed by universities and government agencies (e.g., U.S. Geological Survey or NASA), study dynamic Earth processes at all scales, from its deep interior to the oceans, ice sheets, and atmosphere.

With 12 full-time faculty members and small class sizes, Geophysics students receive individualized attention in a close-knit environment. Given the multidisciplinary nature of geophysics, the undergraduate curriculum equips students with a broad skillset including applied mathematics and physics, geology, computing, and sensor engineering, in addition to theoretical and practical aspects of the geophysical field and laboratory methodologies.

For the past decade, nearly all Mines geophysics graduates have found employment in their chosen field, with about half of them pursuing graduate studies. The program leading to the degree of Bachelor of Science in Geophysical Engineering is accredited by the Engineering Accreditation Commission of ABET: https://www.abet.org/, under the commission's General Criteria with no applicable program criteria.

Bachelor of Science Program in Geophysical Engineering

The Bachelor of Science in Geophysical Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission's General Criteria with no applicable program criteria.

Geophysical Engineering undergraduates interested in professional registration as engineers are encouraged to take the Engineer in Training (EIT)/Fundamentals of Engineering (FE) exam as seniors. The Geophysical Engineering program has the following objectives and associated outcomes:

> Program Educational Objective 1: Graduates will be competent professionals who are capable of independent and innovative problem solving, are skilled in scientific computing, and are working to address important Earth, energy, and /or environmental problems.
>
> Program Educational Objective 2: Graduates will be effective oral and written communicators with exceptional team skills, allowing them to grow in their careers and professional societies.
>
> Program Educational Objective 3: Graduates will recognize the economic and social impacts of their work and will have the ability to communicate this to a range of stakeholders (e.g., management, public, peers)

Graduates with a BS in Geophysical Engineering will demonstrate an ability to:

1. Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare as well as global, cultural, social, environmental, and economic factors.
3. Communicate effectively with a range of audiences.
4. Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. Acquire and apply new knowledge as needed, using appropriate learning strategies.

Geophysics Field Camp

Each summer, a base of field operations is set up for four weeks for students who have completed their junior year. Students prepare geological maps and subsurface models as the basis for applying their multidisciplinary knowledge to design and implement geophysical surveys and integrate and interpret geophysical and geological data to address geoscientific real-world problems. Most recently, the department has focused on using seismic, gravimetric, magnetic, electrical, electromagnetic, and distributed acoustic sensing surveys to understand geothermal systems and hot springs in Colorado. In addition to the required four-week program, students can participate in other diverse field experiences. In recent years, these have included participation in seismic acquisition ships in the Gulf of Mexico, archaeological studies, investigations at environmental sites, and surveys of an active volcano in Hawaii.

Study Abroad

The Department of Geophysics encourages undergraduates to study abroad for one or two semesters. At selected universities abroad, credits can be earned to substitute course requirements in the geophysical engineering program at Mines. The Office of Global Education can provide information on universities that have established formal exchange programs with Mines. Recent exchange programs in which our students have participated include Curtin University, Australia; the University of Edinburgh, Scotland; the University of Leeds, England; and Utrecht University in the Netherlands.

Combined BS/MS Program

Students enrolled in Mines' combined undergraduate/graduate program may double-count up to six credits of graduate coursework to fulfill their undergraduate and graduate degree program requirements. These courses must have been passed with “B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

Summer Jobs in Geophysics

In addition to the summer field camp experience, many Geophysical Engineering students participate in summer internships or research activities in industry, at Mines, or with government agencies such as the U.S. Geological Survey.

Undergraduate Research

Students are encouraged to try their hand at research by working on a project with a Mines faculty member, either during the semester or the summer. This research is often supported by grants or university funds through the Mines Undergraduate Research program (https://www.mines.edu/undergraduate-research). As an alternative to a summer internship, students may participate in a Research Experience for Undergraduates (REU) at either Mines or at another university. REUs are typically sponsored by the National Science Foundation (NSF) and are listed on the NSF website (https://www.nsf.gov/crssprgm/reu/reu_search.jsp).

The Cecil H. and Ida Green Graduate and Professional Center

The meeting rooms, laboratories, and computer-aided instruction areas of the Department of Geophysics are located in the Green Center. The department also maintains equipment for conducting geophysical field measurements, including magnetometers, gravity meters, ground-penetrating radar, and instruments for recording seismic waves. Students may request access to the department petrophysics laboratory to measure the properties of porous rocks or study one of the world's largest repositories of core samples in the Core Lab. The Department also maintains the Ken Larner GeoMaker Space, a collaborative, multidisciplinary workspace for students to design, build, and test their own novel hardware or instruments.

Curriculum

Geophysics is an applied and multidisciplinary science; therefore, students must have a strong foundation in physics, mathematics, geology, and computing. This foundation includes comprehensive courses on the theory and practice of geophysical methods. As geophysics and geophysical engineering involve studying and exploring entire geologic bodies, our graduates have great opportunities to work anywhere on and even off planet Earth. The curriculum includes electives in the Culture and Society (CAS) that give students an understanding of international issues and cultures. Every student who obtains a Bachelor’s Degree in Geophysical Engineering completes the Mines Core Curriculum plus the program-specific courses outlined below. We recommend that students download the current curriculum flowchart (Undergrad Curriculum Flowchart) and work closely with their academic advisor to create an individualized pathway to their degree.

Degree Requirements (Geophysical Engineering)

Freshman

Fall		lec	lab	sem.hrs
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM101	FRESHMAN SUCCESS SEMINAR	1.0		1.0
				15.0

Spring		lec	lab	sem.hrs
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
PHGN100	PHYSICS I - MECHANICS	3.0	3.0	4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
S&W ELECTIVE	SUCCESS AND WELLNESS ELECTIVE			1.0
				15.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
CSCI250	PYTHON-BASED COMPUTING: BUILDING A SENSOR SYSTEM			3.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
GPGN228	INTRODUCTION TO GEOPHYSICS			3.0
HASS200	GLOBAL STUDIES			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				18.0

Spring		lec	lab	sem.hrs
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
GPGN268	GEOPHYSICAL DATA ANALYSIS			3.0

		lec	lab	sem.hrs
GEGN212	THE ROCK CYCLE			4.0
GPGN229	MATHEMATICAL GEOPHYSICS			3.0
				17.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
MATH332	LINEAR ALGEBRA			3.0
MATH201	INTRODUCTION TO STATISTICS			3.0
GPGN328	PHYSICS OF THE EARTH - I	3.0		3.0
GPGN318	APPLIED GEOPHYSICS I			3.0
ELECTIVE	EARTH ELECTIVE	3.0		3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
GPGN404	DIGITAL SIGNAL PROCESSING			3.0
CSCI303	INTRODUCTION TO DATA SCIENCE			3.0
GPGN329	PHYSICS OF THE EARTH - II			3.0
GPGN319	APPLIED GEOPHYSICS II			3.0
FREE	FREE ELECTIVE	3.0		3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective[2]			3.0
				18.0
Summer		**lec**	**lab**	**sem.hrs**
GPGN486	GEOPHYSICS FIELD CAMP		4.0	4.0
				4.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
GPGN436	GEOPHYSICAL COMPUTING			3.0
GPGN409	INVERSION			3.0
GP ELECT	GPGN Advanced Elective[3]	3.0	3.0	3.0
GP ELECT	GPGN Advanced Elective[3]	3.0	3.0	3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective[2]	3.0		3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
GPGN438	GEOPHYSICS PROJECT DESIGN			3.0
GP ELECT	GPGN Advanced Elective[3]	3.0		3.0
GP ELECT	GPGN Advanced Elective[3]			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective[2]	3.0		3.0
FREE	FREE ELECTIVE	3.0		3.0
				15.0

Total Semester Hrs: 132.0

1 Students must take at least 3 credits of GEGN or GEOL electives.
2 Within these 9 Culture and Society (CAS) electives, students must take at least 3 credits at the 400-level.
3 Students must take 12 credits of advanced GPGN elective courses at the 400- or 500-level. At least 6 of these credits must be from geophysical methods courses (GPGN411, GPGN420, GPGN461, and GPGN470).

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- GPGN100 through GPGN599 inclusive

Geophysics Tracks

Beginning in the academic year 23-24, our undergraduate students will have the opportunity to delve deeper into various subjects within Geophysics without the need for additional coursework. Our faculty has approved the implementation of Geophysics tracks, which will provide students with a structured course selection path for gaining advanced knowledge in specific subdisciplines. These tracks include Climate, Energy, Hazards, Humanitarian, Minerals, and Space Geophysics. Many of the courses required for these tracks are already offered within our Geophysics Engineering or other programs, but the defined tracks provide a focused alignment of courses in these areas. It should be noted that participation in these tracks is optional and not required for undergraduate students. They are simply provided as a suggestion for students who wish to gain advanced knowledge in a specific subdiscipline.

Energy Geophysics

Energy Geophysics generates detailed high-resolution images of the Earth interior to access energy resources (hydrocarbons, geothermal, Hydrogen) and facilitate Carbon capture and storage.

Geophysics Electives		
GPGN411	GRAVITY AND MAGNETIC METHODS	3.0
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN461	SEISMIC DATA PROCESSING	4.0
GPGN458	SEISMIC INTERPRETATION	3.0
Earth Electives		
GEOL308	INTRODUCTORY APPLIED STRUCTURAL GEOLOGY	3.0
GEOL309	STRUCTURAL GEOLOGY AND TECTONICS	4.0
GEOL314	STRATIGRAPHY	4.0
GEOL315	SEDIMENTOLOGY AND STRATIGRAPHY	3.0
PEGN308	RESERVOIR ROCK PROPERTIES	3.0
PEGN350	GEOTHERMAL ENERGY	3.0
PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	3.0
CAS and Free Electives		
EBGN201	PRINCIPLES OF ECONOMICS	3.0
PEGN201	PETROLEUM ENGINEERING FUNDAMENTALS	3.0

EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
MATH432	SPATIAL STATISTICS	3.0

Minerals Geophysics

Minerals Geophysics generates detailed high-resolution images of the Earth interior to give access critical minerals necessary to sustain our current and future critical technological and energy needs.

Geophysics Electives		
GPGN411	GRAVITY AND MAGNETIC METHODS	3.0
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN461	SEISMIC DATA PROCESSING	4.0
Earth Electives		
GEOL310	EARTH MATERIALS	3.0
GEOL311	MINING GEOLOGY	3.0
GEGN401	MINERAL DEPOSITS	4.0
GEGN432	GEOLOGICAL DATA MANAGEMENT	3.0
PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	3.0
CAS and Free Electives		
EBGN201	PRINCIPLES OF ECONOMICS	3.0
MNGN210	INTRODUCTORY MINING	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
MATH432	SPATIAL STATISTICS	3.0

Hazard GEOPHYSICS

Hazard Geophysics monitors and quantifies with high temporal and spatial density the occurrence and distribution of destructive Earth hazards (earthquakes, volcano eruptions, tsunamis, and landslides).

Geophysics Electives		
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN455	EARTHQUAKE SEISMOLOGY	3.0
GPGN473	CRYOSPHERE GEOPHYSICS	
Earth Electives		
GEGN432	GEOLOGICAL DATA MANAGEMENT	3.0
GEOL440	PLATE TECTONICS	3.0
GEGN473	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
CEEN419	RISK ASSESSMENT IN GEOTECHNICAL ENGINEERING	3.0
GEGN498A	SURFACE PROCESSES	3.0
CAS and Free Electives		
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
HASS427	RISK COMMUNICATION	3.0
HASS467	HISTORY OF EARTH AND ENVIRONMENTAL SCIENCES	3.0
MATH432	SPATIAL STATISTICS	3.0

Humanitarian Geophysics

Humanitarian Geophysics develops technology in support of human communities for cost effective access to water, safe construction, assessment of soil conditions, and noninvasive subsurface archaeology.

Geophysics Electives		
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN455	EARTHQUAKE SEISMOLOGY	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN474	HYDROGEOPHYSICS	3.0
GPGN461	SEISMIC DATA PROCESSING	4.0
Earth Electives		
GEOL308	INTRODUCTORY APPLIED STRUCTURAL GEOLOGY	3.0
GEOL309	STRUCTURAL GEOLOGY AND TECTONICS	4.0
GEOL314	STRATIGRAPHY	4.0
GEOL315	SEDIMENTOLOGY AND STRATIGRAPHY	3.0
GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
CAS and Free Electives		
EDNS192	DESIGN AND HUMAN VALUES	4.0
EDNS315	ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY	3.0
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
MATH432	SPATIAL STATISTICS	3.0

Climate Geophysics

Climate Geophysics investigates dynamic processes at and near Earth's surface to give insight on physical, thermal, and chemical properties revealing climate evolution affecting communities worldwide.

Geophysics Electives		
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN473	CRYOSPHERE GEOPHYSICS	
GPGN474	HYDROGEOPHYSICS	3.0
Earth Electives		
GEGN466	GROUNDWATER ENGINEERING	3.0
GEOL440	PLATE TECTONICS	3.0
GEGN498A	SURFACE PROCESSES	3.0
CAS and Free Electives		
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
HASS427	RISK COMMUNICATION	3.0
HASS448	GLOBAL ENVIRONMENTAL ISSUES	3.0

HASS484	US WATER POLITICS AND POLICY	3.0
MATH432	SPATIAL STATISTICS	3.0

Space Geophysics

Space Geophysics investigates the surfaces and interiors of planetary bodies to give insight into the Solar System’s formation and evolution, provide access to natural resources, and enable planetary defense.

Geophysics Electives		
GPGN411	GRAVITY AND MAGNETIC METHODS	3.0
GPGN420	ELECTRICAL AND ELECTROMAGNETIC METHODS	3.0
GPGN473	CRYOSPHERE GEOPHYSICS	
GPGN455	EARTHQUAKE SEISMOLOGY	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
Earth Electives		
GEOL410	PLANETARY GEOLOGY	3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
CAS and Free Electives		
EBGN201	PRINCIPLES OF ECONOMICS	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
HASS360	RESEARCH, VALUES, AND COMMUNICATION	3.0
PHGN324	INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS	3.0
HASS427	RISK COMMUNICATION	3.0
MATH432	SPATIAL STATISTICS	3.0

The Mines guidelines for Minor/ASI (p. 30) are in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Minor in Geophysics/Geophysical Engineering

Geophysics plays an important role in many aspects of civil engineering, petroleum engineering, mechanical engineering, and mining engineering, as well as mathematics, physics, geology, chemistry, hydrology, and computer science. Given the natural connections between these various fields and geophysics, it may be of interest for students in other majors to consider choosing to minor in geophysics, or to choose geophysics as an area of specialization. The core set of courses required for a GP minor are as follows:

GPGN229	MATHEMATICAL GEOPHYSICS	3.0
GPGN328	PHYSICS OF THE EARTH - I	3.0
GPGN329	PHYSICS OF THE EARTH - II	3.0
GPGN318 & GPGN319	APPLIED GEOPHYSICS I and APPLIED GEOPHYSICS II	6.0

The remaining 3 credits can be satisfied by a geophysics course or a course in geology, mathematics, or computer science depending on the student’s major. Students must consult with the department of Geophysics to have the remaining course approved. Previous or concurrent experience in programming is strongly recommended but not required.

Courses

GPGN198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN228. INTRODUCTION TO GEOPHYSICS. 3.0 Semester Hrs.
(I) Introduction to sediment, rock, and fluid properties, their measurements, and geophysical applications. Course will introduce physical and mathematical framework, quantitative interpretations, and provide framework for geophysical analyses, data interpretation, and data inversion to help us understand the physical and chemical properties of sediments, rocks, and fluids.
Course Learning Outcomes

- TBD

GPGN229. MATHEMATICAL GEOPHYSICS. 3.0 Semester Hrs.
This course will address how specific mathematical approaches are used to understand and to solve geophysical problems. Topics that will be used in a geophysical context include continuum mechanics, linear algebra, vector calculus, complex variables, Fourier series, partial differential equations, probability, the wave equation, and the heat equation. 3 hours lecture; 3 semester hours. Prerequisite: MATH213, PHGN200. Co-requisite: MATH225.
Course Learning Outcomes

- TBD

GPGN268. GEOPHYSICAL DATA ANALYSIS. 3.0 Semester Hrs.
Geophysical Data Analysis focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. Students work on projects from the geophysical engineering practice in which they analyze (process, model, visualize) data. In their projects, students encounter limitations and uncertainties in data and learn quantitative means for handling them. They learn how to analyze errors in data, and their effects on data interpretation and decision making. 3 lecture hours; 3 semester hours. Prerequisite: CSCI128.

GPGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN318. APPLIED GEOPHYSICS I. 3.0 Semester Hrs.
Applied Geophysics I is an introductory course on the application of static fields to image the Earth's subsurface. The static fields include electrostatics, magnetostatics, and gravitational field. These tools are employed in various geotechnical and environmental engineering problems, resource exploration and production monitoring, geothermal site characterization, hazards, and humanitarian efforts. Through the combination of two one-hour lectures and one three-hour lab each week, the students are provided with the fundamental theory and hands-on field experiments for each of these techniques, including the principles, instrumentation, and procedures of data acquisition, analysis, and interpretation. Co-requisite: GPGN328.
Course Learning Outcomes

- 1) Design electrical, magnetic, and gravity field experiments to investigate geoscience questions
- 2) Apply electrical, magnetic, and gravity concepts and theory learned in the classroom to a natural setting to answer geoscience questions
- 3) Synthesize geoscience datasets with geophysical (electrical, magnetic, and gravity) theory to develop a scientific interpretation
- 4) Create field experiments and data processing approaches that ensure repeatability and reproducibility
- 5) Communicate scientific results and their uncertainty clearly and effectively using written, verbal, and/or visual media
- 6) Develop personal, interpersonal, and scientific skills to safely and efficiently collect, process, and interpret geoscience data in a collaborative setting

GPGN319. APPLIED GEOPHYSICS II. 3.0 Semester Hrs.
Applied Geophysics II is an introductory course on the application of dynamic fields (electromagnetic and seismic) to image the Earth's subsurface. These tools are employed in various geotechnical and environmental engineering problems, resource exploration and production monitoring, geothermal site characterization, hazards, and humanitarian efforts. Through the combination of two one-hour lectures and one three-hour lab each week, the students are provided with the fundamental theory and hands-on field experiments for each of these techniques, including the principles, instrumentation, and procedures of data acquisition, analysis, and interpretation. Co-requisite: GPGN329.
Course Learning Outcomes

- 1) Design seismic and electromagnetic field experiments to investigate geoscience questions
- 2) Apply seismic and electromagnetic concepts and theory learned in the classroom to a natural setting to answer geoscience questions
- 3) Synthesize geoscience datasets with geophysical (electromagnetic and seismic) theory to develop a scientific interpretation
- 4) Create field experiments and data processing approaches that ensure repeatability and reproducibility
- 5) Communicate scientific results and their uncertainty clearly and effectively using written, verbal, and/or visual media
- 6) Develop personal, interpersonal, and scientific skills to safely and efficiently collect, process, and interpret geoscience data in a collaborative setting

GPGN328. PHYSICS OF THE EARTH - I. 3.0 Semester Hrs.
This course is the first part of a two-course sequence on Physics of the Earth and will introduce the static fields including the electrostatics, steady state current flow in conductive media, magnetostatics, and gravitational field as used in probing the interior of the Earth and physical processes therein. The spatial context will be earth's lithosphere and the associated geoscientific problems arise from a wide range of disciplines including environmental problems, hydrology, minerals and energy exploration, hydrology, tectonics, and climate science. The course will discuss static field theory, their interaction with different physical properties of earth materials, and the use of these fields in imaging, characterizing, and monitoring structures and processes in the earth lithosphere and on the interface between atmosphere and crust. 3 hours lecture; 3 semester hours. Prerequisite: GPGN229. Co-requisite: GPGN318.
Course Learning Outcomes

- TBD

GPGN329. PHYSICS OF THE EARTH - II. 3.0 Semester Hrs.
The second half of Physics of the Earth will aim to give a global perspective to Earth's formation and evolution. Starting from conservation laws and continuum mechanics, Earth's dynamic fields (theory of seismic and electromagnetic wave propagation) will be covered in the context of solid-Earth geophysics and integrated with various geophysical observations & measurements; the Earth seen by the waves, inferring the structure and composition of the interior of planetary bodies from crust to core, physical & thermo-chemical processes in mantle and core shaping Earth's surface and magnetic field, planetary cooling, "hot topics" and current challenges in illuminating Earth's deep structure, modern computational techniques that are used to improve our understanding of Earth's interior and history. 3 hours lecture; 3 semester hours. Prerequisite: GPGN328. Co-requisite: GPGN319.
Course Learning Outcomes

- Using math and physics to investigate Earth's formation and evolution.
- Investigating Earth's deep interior and adressing global-scale geophysical and geodynamical problems.
- Recent advances in (computational) global geophysics
- Reports of written and computer-based assignments

GPGN398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN404. DIGITAL SIGNAL PROCESSING. 3.0 Semester Hrs.
The fundamentals of digital signal processing as applied to geophysical investigations are studied. Students explore the mathematical background and practical consequences of Fourier series and 1D/2D Fourier transforms, linear time-invariant (LTI) systems, convolution and deconvolution, properties of discrete systems, sampling theorem and signal reconstruction, Z-Transforms, discrete-time Fourier transform, discrete Fourier series and discrete Fourier transform, windowing and spectrograms, realization of digital filters, FIR filter design and IIR filter design. Emphasis is placed on applying the knowledge gained in lecture to exploring practical signal processing issues. This is done through homework and in-class practicum assignments requiring the programming and testing of algorithms discussed in lecture. 2

hours lecture; 3 hours lab; 3 semester hours. Prerequisite: GPGN268, CSCI250, MATH225, MATH332.
Course Learning Outcomes

- Learning and exploiting similarities between concepts learned in calculus, differential equations, and elsewhere, and how they appear in the context of digital signal analysis
- Understanding how to use discrete Fourier transforms in the analysis and processing of digital signals. Learning how to digitally sample continuous analog signals, reconstruct continuous signals from sampled
- Learning how to digitally sample continuous analog signals, reconstruct continuous signals from sampled ones, and the conditions under which this reconstruction is feasible.
- Learning the pitfalls and tradeoffs in the design and application of common digital filters.
- Independently design, develop, validate and apply computer programs to solve digital signal analysis and processing tasks, largely using the Python language and its associated tool kits (i.e., Numpy, Scipy and Matplotlib).
- Gain experience in chosing and applying 1D/2D filters to achieve specific filtering tasks through a range of numerical exercises and an independent project.

GPGN409. INVERSION. 3.0 Semester Hrs.
This course provides an in-depth study of the fundamentals of inverse problem theory and its application to geophysics. Inversion technology is widely applicable in all areas of geophysical investigation, regardless of the physics employed, as well as in non-geophysical data analysis. The course will cover essential concepts of inversion in both probabilistic and deterministic frameworks and practical methods for solving discrete inverse problems. Specific topics to be explored include model and data discretization, Bayesian inversion, optimization criteria and methods, regularization techniques, and error and uncertainty analysis. Weekly homework assignments will require students to solve theoretical or numerical problems using programming assignments illustrating the concepts discussed in class. Knowledge of the Python programming language is assumed. 3 hours lecture; 3 semester hours. Prerequisite: GPGN329, GPGN404.
Course Learning Outcomes

- Formulate discrete GP inverse problems, capturing optimal parameterization and uncertainty
- Design numeric solutions to GP inverse problems using high-level programming environments
- Process and extract information from uncertain field data by quantifying the reliability of inversion results
- Report results orally and in writing based on reproducible numeric experiments

GPGN410. MACHINE LEARNING INVERSION IN APPLIED GEOSCIENCE. 3.0 Semester Hrs.
This course presents the fundamentals of formulating and solving inverse problems when the models to be recovered are functions in applied geosciences. The emphases are on the basic strategies for solving linear and nonlinear inverse problems and on the practical methodologies for constructing models that can be directly used in subsequent simulations and interpretations. The course will cover model construction and uncertainty quantification using Tikhonov regularization, machine learning (ML), and generative artificial intelligence. The course will and integration of information the data to be inverted and the information in the complementary data that are conceptual in nature. Prerequisite: None. Co-requisite: None.
Course Learning Outcomes

- Understanding and skills in the classical regularized inversion for model construction and appraisal
- Understanding and skills in the emerging machine learning and artificial intelligence inversions and uncertainty quantification.
- Understanding in information transfer and extraction through inversion for decision-making in applied geosciences

GPGN411. GRAVITY AND MAGNETIC METHODS. 3.0 Semester Hrs.
This course studies the theory and methods for processing and interpreting gravity and magnetic data acquired in geosciences and aims to enhance students' knowledge and skills in the application of gravity and magnetic methods. The course covers four major topic areas: (1) the data quantities measured in field surveys, (2) the methods for modeling, processing, and analyzing gravity and magnetic data; (3) 3D inversion of gravity, gravity gradient, and magnetic data; and (4) integrated interpretation of gravity and magnetic data through inversion and geology differentiation for extracting geology information. 3 hours lecture; 3 semester hours. Prerequisite: GPGN328, GPGN404.
Course Learning Outcomes

- 1. Have an understanding of the fundamental aspects of potential-field theory
- 2. Have enhanced their ability to model and process potential-field data
- 3. Have gained understanding and techniques for quantitative interpretation of potential-field data through inversions
- 4. Have an understanding of interpreting magnetic data affected by strong remanent magnetization

GPGN420. ELECTRICAL AND ELECTROMAGNETIC METHODS. 3.0 Semester Hrs.
Equivalent with GPGN422,
In-depth study of the application of electrical and electromagnetic methods to crustal studies, minerals exploration, oil and gas exploration, and groundwater. Laboratory work with mathematical models coupled with field work over areas of known geology. 3 hours lecture; 3 semester hours. Prerequisite: GPGN329, GPGN404.
Course Learning Outcomes

- An ability to apply knowledge of mathematics, science and engineering
- An ability to design and conduct experiments, as well as to analyze and interpret data
- An ability to communicate effectively
- An ability to analyze, quantitatively, the errors, limitations, and uncertainties in data

GPGN436. GEOPHYSICAL COMPUTING. 3.0 Semester Hrs.
Equivalent with GPGN435,
This course develops the principles of geophysical computing in the context of simulating and validating numerical solutions to geophysical data processing challenges (e.g., interpolation, regression, and numerical differentiation) and partial differential equations commonly found in geophysical investigations (e.g., Laplace/Poisson equation, heat flow/diffusion equation, acoustic wave equation). Students learn how algorithms from applied linear algebra can be leveraged to efficiently generate numerical solutions to multidimensional geophysical problems

using both self-developed and existing numerical libraries. Offered concurrently with GPGN536.. Prerequisite: GPGN329, GPGN404.
Course Learning Outcomes

- Students will understand and be able to take theoretical concepts and use them to develop, prototype and validate numerical algorithms in the context of geophysical computing.
- Students will develop practical programming skills and combine with knowledge of numerical algorithms to solve real-world geophysical problems.
- Students will develop independent research skills by undertaking a project involving a substantial piece of analytic, numerical and computation work involving solving a real-world geophysical problem

GPGN438. GEOPHYSICS PROJECT DESIGN. 3.0 Semester Hrs.
(WI) Capstone design course for seniors majoring in Geophysics. Working either individually or on a team, students apply engineering design principles to solve a geophysical problem, leading to a project report or senior thesis and oral presentation thereof. Choice of design project is to be arranged between a student and the faculty member, who will serve as the project's advisor, subject to the instructor's approval. 1 hour lecture; 6 hours lab; 3 semester hours. Prerequisites: GPGN329.
Course Learning Outcomes

- 1. an ability to apply knowledge of mathematics, science, and engineering.
- 2. an ability to design and conduct experiments, as well as to analyze and interpret data
- 3. an ability to design a system, a component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health, safety, manufacturability, and sustainability
- 4. an ability to identify, formulate, and solve engineering problems
- 5. an understanding of professional and ethical responsibility
- 6. an ability to communicate effectively
- 7. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

GPGN455. EARTHQUAKE SEISMOLOGY. 3.0 Semester Hrs.
Equivalent with GPGN555,
Earthquakes are amongst the most significant natural hazards faced by mankind, with millions of fatalities forecast this century. They are also our most accessible source of information on Earth's structure, rheology and tectonics, which are what ultimately govern the distribution of its natural resources. This course provides an overview of how earthquake seismology, complemented by geodesy and tectonic geomorphology, can be used to determine earthquake locations, depths and mechanisms; understand Earth's tectonics and rheology; establish long-term earthquake histories and forecast future recurrence; mitigate against seismic hazards; illuminate large- and fine-scale features of Earth's interior using earthquake data. Students will also cover the recent developments in 3D numerical earthquake source and wave propagation modelling as well as common & modern seismic data formats and processing/visualization tools and techniques used in earthquake seismology. 3 hours lecture; 3 semester hours. Prerequisite: GPGN329, GPGN404.
Course Learning Outcomes

- Theory of wave propagation & earthqauke source (point and finite-source models).
- Acoustic - elastic wave simulations, observational seismology, seismic data processing, source and structural modelling.
- Recent advances in earthquake seismology: 3D wave simulations, big data and high-performance computing of wave simulations, earthquake source modelling and seismic tomography
- Modern seismic data formats and data processing/visualization tools, numerical solvers for seismic wave propagation, etc.

GPGN458. SEISMIC INTERPRETATION. 3.0 Semester Hrs.
This course gives participants an understanding of how to model, understand, interpret and analyze seismic data in a quantitative manner on several worldwide projects. When you look at seismic data, how does it relate to the rock properties, what do the amplitudes mean, what is tuning, what is a wavelet, how does the seismic relate to structure, and what are seismic attributes and inversion products? How do you use this information in exploration, production and basic volumetric and economics calculations? The course will go over these topics. Students will work in teams on several modeling and seismic field data exercises around the world in most widely used software platforms (Ikon-RokDoc, Schlumberger-Petrel, GEOX, CGG-HampsonRussell). The course aims to give participants knowledge and information to assist in professional and career development and to be operationally prepared for the work environment. Prerequisites: GPGN461.
Course Learning Outcomes

- Learning how to interpret seismic data through lectures and labs.

GPGN461. SEISMIC DATA PROCESSING. 4.0 Semester Hrs.
Equivalent with GPGN452,
This course covers the basic processing steps required to create images of the earth using 2D and 3D reflection seismic data. Topics include data organization and domains, signal processing to enhance temporal and spatial resolution, identification and suppression of incoherent and coherent noise, velocity analysis, near-surface statics, datuming, normal- and dip-moveout corrections, common-midpoint stacking, principles and methods used for poststack and prestack time and depth imaging, and post-imaging enhancement techniques. Field data are extensively used throughout the course. A three-hour lab introduces the student to hands-on data processing using a Seismic Unix software package. The final project consists of processing a 2D seismic line with oral presentation of the results. 3 hours lecture; 3 hours lab; 4 semester hours. Prerequisite: GPGN404, GPGN329.
Course Learning Outcomes

- 1. Demonstrate knowledge and understanding of basic seismic data processing steps.
- 2. Successfully process a 2D marine seismic line using Seismic Unix. Design a processing sequence, evaluate possible processing steps, and apply appropriate quality-control tests to guide the data.

GPGN470. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.
An introduction to geoscience applications of satellite remote sensing of the Earth and planets. The lectures provide background on satellites, sensors, methodology, and diverse applications. Topics include visible, near infrared, and thermal infrared passive sensing, active microwave and radio sensing, and geodetic remote sensing. Lectures and labs involve use of data from a variety of instruments, as several applications to problems in the Earth and planetary sciences are presented. Students will complete independent term projects that are presented both written and orally at the end of the term. 3 hours lecture; 3 semester hours. Prerequisite: CSCI128.

Course Learning Outcomes

- TBD

GPGN474. HYDROGEOPHYSICS. 3.0 Semester Hrs.
Application of geophysical methods to problems in hydrology. The course will consider both groundwater and surface water problems from the micro to basin scale. Topics may include characterizing groundwater surface water interaction, critical zone evaluation and weathering processes, snow and ice as a water resource, large scale imaging of aquifer systems, in situ estimation of aquifer parameters, evaluation of groundwater resources, delineation of thermal and chemical pollution of groundwater, and mapping of saltware intrusion. Readings and discussions will touch on social and political issues surrounding water use and the critical role that physical characterization plays in understanding water resources. 2 hours lecture; 3 hours lab; 3 semester hours.
Course Learning Outcomes

- TBD

GPGN486. GEOPHYSICS FIELD CAMP. 4.0 Semester Hrs.
(WI) Introduction to geological and geophysical field methods. The program includes exercises in geological surveying, stratigraphic section measurements, geological mapping, and interpretation of geological observations. Students conduct geophysical surveys related to the acquisition of seismic, gravity, magnetic, and electrical observations. Students participate in designing the appropriate geophysical surveys, acquiring the observations, reducing the observations, and interpreting these observations in the context of the geological model defined from the geological surveys. 12 hours lab; 4 semester hours. Prerequisite: GPGN318,GPGN319, GPGN404, GEGN212.
Course Learning Outcomes

- a. an ability to apply knowledge of mathematics, science and engineering b. an ability to design and conduct experiments, as well as to analyze and interpret data c. an ability to function on multidisciplinary teams d. an ability to identify, formulate, and solve engineering problems e. an understanding of professional and ethical responsibility f. an ability to communicate effectively 2. an ability to analyze, quantitatively, the errors, limitations, and uncertainties in data

GPGN498. SPECIAL TOPICS IN GEOPHYSICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN498. SPECIAL TOPICS IN GEOPHYSICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN498. SPECIAL TOPICS IN GEOPHYSICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN499. GEOPHYSICAL INVESTIGATION. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

SYGN498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

Professors Emeriti

Thomas L. Davis

Dave Hale

Kenneth L. Larner

Gary R. Olhoeft

Phillip R. Romig, Jr.

Terence K. Young

Emeritus Associate Professor

Thomas M. Boyd

University Distinguished Professors

Kamini Singha

Ilya D. Tsvankin

Professors

John H. Bradford, Vice President for Global Initiatives

Brandon Dugan, Associate Department Head, Baker Hughes Chair of Petrophysics and Borehole Geophysics

Yaoguo Li

Manika Prasad

Paul C. Sava, Department Head, C.H. Green Chair of Exploration Geophysics

Jeffrey C. Shragge

Roelof K. Snieder, Keck Foundation Professor of Professional Development Education

Ilya D. Tsvankin

Ali Tura

Associate professors

Ge Jin

Eileen Martin

Matthew Siegfried

Assistant Professors

Bia Villas Bôas

Joint appointment with loci within Geophysics

Eileen Martin, Associate Professor, Applied Mathematics and Statistics

Joint appointment with loci outside of Geophysics

Eric Anderson, Associate Professor, Civil and Environmental Engineering

Ebru Bozdag, Associate Professor, Applied Mathematics and Statistics

Elizabeth Reddy, Assistant Professor, Engineering, Design and Society

Danica Roth, Assistant Professor, Geology and Geological Engineering

Kamini Singhi, Professor, Geology and Geological Engineering

Research Professor

Jeffrey Lee

Research Associate Professors

Richard Krahenbuhl

James L. Simmons

Research Assistant Professor

Mengli Zhang

Affiliate Faculty

Jyoti Behura, Founder & CEO, Seismic Science LLC

Timothy Collett, Senior Scientist, US Geological Survey

Morgan Moschetti, Research Geophysicist, US Geological Survey

Ryan North, Principal Geophysicist, ISC Geoscience

Nathaniel Putzig, Senior Scientist, Planetary Science Institute

Andrei Swidinsky, Associate Professor, University of Toronto

Whitney Trainor-Guitton, Geoscience Researcher, National Renewable Energy Laboratory

David Wald, Research Geophysicist, US Geological Survey

Joint Appointments

Fred Day-Lewis, Chief Geophysicist, Pacific Northwest National Laboratory

Humanities, Arts, and Social Sciences

Program Description

As the twenty-first century unfolds, individuals, communities, and nations face major challenges in energy, natural resources, and the environment. While these challenges demand practical ingenuity from engineers and applied scientists, solutions must also take into account social, political, economic, cultural, ethical, and global contexts. Mines students, as citizens and future professionals, confront a rapidly changing society that demands core technical skills complemented by flexible intelligence, original thought, and cultural sensitivity.

Courses in Humanities, Arts, and Social Sciences Department (HASS) expand students' professional and personal capacities by providing opportunities to explore the humanities, social sciences, and fine arts. Our curricula encourage the development of critical thinking skills that will help students make more informed choices as national and world citizens – promoting more complex understandings of justice, equality, culture, history, development, and sustainability. Students, for example, study ethical reasoning, compare and contrast different economies and cultures, develop arguments from data, and interrogate globalization. HASS courses also foster creativity by offering opportunities for self-discovery. Students conduct literary analyses, improve communication skills, play music, learn media theory, and write poetry. These experiences foster intellectual agility, personal maturity, and respect for the complexity of the world.

Undergraduate Humanities and Social Science

Educational Objectives

In addition to contributing to the educational objectives described in the Mines Graduate Profile and the ABET accreditation criteria, the coursework in the department of Humanities, Arts, and Social Sciences is designed to help Mines develop in students the ability to engage in life-long learning and recognize the value of doing so by acquiring the broad education necessary to

1. Understand the impact of engineering solutions in contemporary, global, international, societal, political, and ethical contexts.
2. Understand the role of Humanities and Social Sciences in identifying, formulating, and solving engineering problems.
3. Prepare to live and work in a complex world,
4. Understand the meaning and implications of “stewardship of the Earth."
5. Communicate effectively in writing and orally.

Music (LIMU)

Courses in Music do not count toward the Culture and Society restricted-elective requirement, but may be taken for **free elective credit only. A maximum of 3 semester hours of concert band, chorus, physical education, athletics, or other activity credit combined may be used toward free elective credit in a degree-granting program.**

Foreign Language (LIFL)

Typically, several foreign languages are taught through the department. In order to gain basic proficiency from their foreign language study, students are encouraged to enroll for at least two semesters in whatever language(s) they elect to take. **No student is permitted to take a foreign language that is either his/her native language or second language.**

Undergraduate Minors

At the undergraduate level, Humanities, Arts, and Social Sciences offers minors in Culture, Creativity, and Communication; Environment and Sustainability Studies; Global Politics and Society; Music, Audio Engineering, and Recording Arts; and an Individualized Undergraduate minor. See the minor tab for details.

Graduate Degree and Programs

At the graduate level, Humanities, Arts, and Social Sciences offers a 30-hour degree. It also offers graduate certificates and graduate minors in Natural Resources and Energy Policy (NREP). See the graduate catalog for details.

Hennebach Program in the Humanities

The Hennebach Program in the Humanities, supported by a major endowment from Ralph Hennebach (CSM class of 1941), sponsors a regular series of Visiting Professors and the general enhancement of the humanities on campus. Recent visiting professors have included scholars in Classics, Creative Writing, Environmental Studies, Ethics, History, Literature, Philosophy, and Social Theory as well as the interdisciplinary fields of Environmental Policy and Science, Technology, and Society Studies. The program is dedicated to enriching the lives of both students and faculty through teaching and research, with visiting scholars offering courses, giving lectures, conducting workshops, and collaborating on projects. In addition, the Hennebach Program is exploring opportunities for meeting the needs of undergraduate students who would especially benefit from more focused study in the humanities that would appropriately complement technical degree curricula.

Culture and Society

Culture and Society courses provide cultural and social perspectives to advance students' understanding of the contemporary, global world. These courses help students contextualize scientific and technical knowledge and practice to better understand their potential impacts on people, organizations, the economy, and the environment. Culture and Society courses also enhance students' abilities to communicate, explore diverse perspectives, and grapple with ethics and professional responsibilities. Ultimately, these courses provide the opportunity for students to explore what it means to be human in an interconnected world.

The 9 credits of mid-level and 400-level CAS electives must meet the following requirements:

- At least 3 credits must be at the 400-level.
- At least 3 credits must have a HASS course code.
- No more than 6 credits can have the LIFL (Foreign Languages) course code.
- Courses with the LIMU (Music) course code cannot be used to satisfy this requirement.
- HASS498 special topic courses can be used to satisfy this requirement.#EBGN498 andEDNS498 special topic courses will be determined to satisfy this requirement on a course-by-course basis, and that determination will be made prior to the beginning of the term the course is offered.
- Except for foreign languages, no AP or IB credit can be used to meet this requirement. (AP/IB credits will be applied as free electives.)
- Single majors in Economics cannot use courses with the EBGN course code to satisfy this requirement.

Culture and Society Electives

HASSXXX	All courses with the HASS prefix are eligible for CAS credit	
LIFLXXX	All LIFL courses are eligible for CAS (midlevel) credit	
HNRSXXX	All HNRS courses are eligible for CAS credit (see your advisor)	
Economics and Business Courses approved for CAS credit		
EBGN201	PRINCIPLES OF ECONOMICS	3.0
EBGN301	INTERMEDIATE MICROECONOMICS	3.0
EBGN302	INTERMEDIATE MACROECONOMICS	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
EBGN320	ECONOMICS AND TECHNOLOGY	3.0
EBGN330	ENERGY ECONOMICS	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
EBGN430	ADVANCED ENERGY ECONOMICS	3.0
EBGN434	PROPERTY RIGHTS AND NATURAL RESOURCES	3.0
EBGN437	REGIONAL ECONOMICS	3.0
EBGN441	INTERNATIONAL ECONOMICS	3.0
EBGN443	PUBLIC ECONOMICS	3.0
EBGN470	ENVIRONMENTAL ECONOMICS	3.0
Engineering, Design, and Society courses approved for CAS credit		
EDNS315	ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY	3.0
EDNS477	ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT	3.0
EDNS478	ENGINEERING AND SOCIAL JUSTICE	3.0
EDNS479	COMMUNITY-BASED RESEARCH	3.0
EDNS480	ANTHROPOLOGY OF DEVELOPMENT	3.0
Other courses approved for CAS credit		
MNGN335	COMMUNITIES AND NATURAL RESOURCE DEVELOPMENT	3.0
PEGN430	ENVIRONMENTAL LAW AND SUSTAINABILITY	3.0
SCED333	EDUCATIONAL PSYCHOLOGY AND ASSESSMENT	3.0
SCED363	DYNAMIC TEACHING: MOTIVATION, CLASSROOM MANAGEMENT, AND DIFFERENTIATION OF INSTRUCTION	3.0
SCED415	SCIENTIFIC PRACTICES VS ENGINEERING DESIGN AND THE NATURE OF SCIENCE	3.0

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Minor Programs

The Department of Humanities, Arts, and Social Sciences Studies (HASS) offers several minor programs. Students who elect to pursue a minor **usually** will satisfy the Culture and Society (CAS) requirements; however, the Music Technology ASI will not satisfy these requirements. Students will need to use free elective hours to complete a minor.

A minor requires a minimum of 18 credit hours; an area of special interest (ASI) requires a minimum of 12 credit hours. No more than half the credits to be applied toward a Humanities, Arts, and Social Sciences minor or ASI may be transfer credits. The Humanities, Arts, and Social Sciences undergraduate faculty advisor must approve all transfer credits that will be used for a Humanities, Arts, and Social Sciences minor or ASI.

The student must fill out a Minor/Area of Special Interest Declaration (available in the Registrar's Office) and obtain approval signatures from the student's Mines advisor, from the head or director of the student's major department or division, and from the Humanities, Arts, and Social Sciences faculty undergraduate advisor. Students should consult the listed program directors for the specific requirements of each minor.

The available minors or ASI's are listed below with their program directors.

Culture, Creativity, and Communication (CCC), Paul Farca; Environment and Sustainability Studies (ESS), Tina Gianquitto; Global Politics and Society (GPS), Derrick Hudson; Individualized Minor, Sandy Woodson.

Minor in Culture, Creativity, and Communication

Given the diverse disciplinary and interdisciplinary interests of Mines students, the Culture, Creativity, Communication minor provides a flexible, interdisciplinary range of options so students can follow particular passions bolstered by distinctive, signature experiences. Students will take courses below as part of a pathway in Literature and Creative Writing, a pathway in Communication Studies, or an intellectually coherent pathway in both.

The CCC minor elevates student capacity for empathy, contextual understanding, intellectual versatility, creative cognition, and expressive clarity. This minor will help students who feel a passion for culture and the arts, and who yearn to explore diverse fields of literary studies, creative writing, and communication studies.

Students in the Culture, Creativity, Communication minor must complete 18 hours of coursework, selected with the guidance of a faculty advisor, from the courses below.

Midlevel courses:

HASS303	FOUNDATIONS: THE ART AND CRAFT OF THE CREATIVE WRITING WORKSHOP	3.0
HASS201/303	WORKSHOP FOUNDATIONS: THE ART AND CRAFT OF CREATIVE WRITING (HASS201 new course number Spring2022->changed to HASS303)	3.0
or HASS303	FOUNDATIONS: THE ART AND CRAFT OF THE CREATIVE WRITING WORKSHOP	
HASS302	FOUNDATIONS IN CREATIVE WRITING	3.0
HASS300/300	INTERMEDIATE FICTION (Course number change Spring 2022->Now HASS302)	3.0
or HASS300	INTERMEDIATE FICTION	
HASS301	INTERMEDIATE POETRY WRITING WORKSHOP	3.0
HASS305	AMERICAN LITERATURE: COLONIAL PERIOD TO THE PRESENT	3.0
HASS307	EXPLORATIONS IN COMPARATIVE LITERATURE	3.0
HASS309	LITERATURE AND SOCIETY	3.0
HASS320	ETHICS	3.0
HASS323	INTRODUCTION TO SCIENCE COMMUNICATION	3.0

400-level courses (minimum of two):

HASS400	ADVANCED SHORT FICTION WRITING WORKSHOP	3.0
HASS401	ADVANCED POETRY WRITING WORKSHOP	3.0
HASS404	WOMEN, LITERATURE, AND SOCIETY	3.0
HASS406	THE LITERATURE OF WAR AND REMEMBRANCE	3.0
HASS407	SCIENCE IN LITERATURE	3.0
HASS408	CREATIVE NONFICTION WRITING: LIFE STORIES	3.0
HASS410	CRITICAL PERSPECTIVES ON 20TH CENTURY LITERATURE	3.0
HASS411	LITERATURES OF THE AFRICAN WORLD	3.0
HASS412	LITERATURE AND THE ENVIRONMENT	3.0
HASS415	MASS MEDIA STUDIES	3.0
HASS416	FILM STUDIES	3.0
HASS418	NARRATING THE NATION	3.0
HASS419	ENVIRONMENTAL COMMUNICATION	3.0
HASS423	ADVANCED SCIENCE COMMUNICATION	3.0
HASS425	INTERCULTURAL COMMUNICATION	3.0
HASS433	SHAKESPEARE AND THE SCIENTIFIC REVOLUTION	3.0

Minor in Environment and Sustainability Studies

As environmental challenges mount across the world, governmental agencies, policy makers, industry, and others will look to engineers and scientists to develop innovative solutions to meet these pressing demands.

The Environment and Sustainability Studies minor provides political, social, cultural, economic, and historical perspectives on modern environmental challenges and equips students with the critical and analytical tools required to address contemporary environmental challenges. The curriculum further encourages students to transcend disciplinary boundaries by providing opportunities to integrate and synthesize the many strands of knowledge that bear on environmental issues. When combined with their technical, engineering, and/or scientific degrees, graduates will have added marketable skills, which can also be translated into environmental careers, or post-graduate programs.

The Minor in Environment and Sustainability Studies requires 18 credits of coursework:

- 15 credits of Culture and Society (CAS) electives, and
- 3 credits of restricted environmental science and engineering electives*

*Faculty involved in the Environment and Sustainability Studies minor will work with colleagues across campus to identify upper-division electives in environmental science and engineering that can fulfill this requirement.

Students may also include up to 3 credits of independent study with the approval of the ESS Director.

Courses

HASS200: Global Studies: Environment: Students interested in the ESS Minor are encouraged to sign up for the Global Studies section focused on the environment. Please contact ESS Minor director for information on when this course is offered each semester.

Minor requirements

- Choose five courses from the CAS list. At least three courses must be from HASS, with one at the 400-level. Up to two courses can be from Economics and Business (EBGN), Engineering, Design, and Society (EDNS), or the approved courses from Geology and Geophysics (GEOC) and Petroleum Engineering (PEGN).
- Choose one course from the restricted STEM electives. Other courses may be approved by the ESS director.

Minor in Global Politics and Society (GPS)

The GPS minor (18 credits) prepares engineers and scientists with the knowledge and experience they need to tackle complex global issues and become leaders in their professional and personal lives within their own countries and in the global community. Drawing primarily from the social sciences, our classes link theories with real-world problems while enhancing students' analytical and communication skills. Courses provide the political, social, and historical contexts to better understand world regions, particularly ones with significant natural resource endowments. Topics include war, trade, energy, corruption, and religion. Fitting the Mines' mission, our courses bring a stronger focus to natural resources and energy issues than similar programs at other universities.

Required Course: One of the following two courses

HASS460	GEOPOLITICS OF NATURAL RESOURCES	3.0
HASS344	INTERNATIONAL RELATIONS	3.0

Electives

The remaining credits must come from the following courses. AT LEAST one must be a 400-level class.

Regional Focus		
HASS339	MIDDLE EAST: POLITICS & SOCIETY	3.0
HASS411	LITERATURES OF THE AFRICAN WORLD	3.0
HASS437	ASIAN DEVELOPMENT	3.0
HASS439	MIDDLE EAST DEVELOPMENT	3.0
Global Focus		
HASS307	EXPLORATIONS IN COMPARATIVE LITERATURE	3.0
HASS431	MORAL PSYCHOLOGY, RELIGION, AND AMERICAN SOCIETY	3.0
HASS490	ENERGY AND SOCIETY	3.0
Politics and Policy Focus		
HASS486	SCIENCE AND TECHNOLOGY POLICY	3.0
HASS488	GLOBAL WATER POLITICS AND POLICY	3.0
HASS491	ENERGY POLITICS	3.0
Foreign Languages		
LIFL1XX	FOREIGN LANGUAGE Up to six hours	3-6

Minor in Music, Audio Engineering, and the Recording Arts

Program Advisor: Jonathan Cullison

The Music, Audio Engineering, and the Recording Arts minor is designed for students interested in the crossover field between music and related technical skills. Technical emphasis within this minor creates an opportunity for the student to research/experience the impact of their specific majors upon both music as an art form and music as an industry. Throughout the minor, students are exposed to the refinements and developments that technology has created in the field of recording, production, sound reinforcement, and product design as well as the interplay between the arts and technology. The discovery of connections between current music and sound engineering practices is stressed. The final outcome is a skilled and informed studio musician/technician in present-day studio conditions. Finally, this minor is not designed to expand any current engineering curriculum, but to complement a student's education.

Students desiring a Music, Audio Engineering, and the Recording Arts Minor must complete 18 credits of courses as follows:

Four *required* music courses (12 credits):

HASS324	AUDIO/ACOUSTICAL ENGINEERING AND SCIENCE	3.0
HASS327	MUSIC TECHNOLOGY	3.0
HASS315	MUSICAL TRADITIONS OF THE WESTERN WORLD	3.0
HASS330	MUSIC TECHNOLOGY CAPSTONE	3.0
Total Semester Hrs		**12.0**

One 400-level *required* course (3 credits):

HASS429	REAL WORLD RECORDING/RESEARCH	3.0

Three additional credits:

HASS326	MUSIC THEORY	3.0
Performance Enhancement (3 credits total)		
LIMU	ENSEMBLE Two semesters	
LIMU189	INDIVIDUAL INSTRUMENTAL OR VOCAL MUSIC INSTRUCTION One semester	

Individualized Undergraduate Minor

Program Advisor: Prof. Sandy Woodson. Students declaring an Undergraduate Individual Minor in LAIS must choose 18 restricted-elective credits in LAIS with a coherent rationale reflecting some explicit focus of study that the student wishes to pursue. A student desiring this minor must design it in consultation with a member of the LAIS faculty who approves the rationale and the choice of courses, e.g., pre-law or pre-med courses.

Area of Special Interest in Music Technology

Program Advisor: Prof. Bob Klimek. The Area of Special Interest in Music Technology is comprised of a sequence of courses that allows students to combine interests and abilities in both the science and theory of music production. Completion of this ASI will train students in the technical aspects of the music recording industry, including sound and video recording, sound effects, and software design.

Courses

HASS100. NATURE AND HUMAN VALUES. 3.0 Semester Hrs.
Equivalent with CSM191,CSM192,HNRS105,HNRS115,HNRS198A,LAIS100,
Nature and Human Values (NHV) is a writing-intensive course, workshop, and discussion seminar that focuses on ethics and inquiry and uses humanities perspectives to examine big questions about the interdependence of human life, society, and the environment. The class links personal, professional, and environmental ethics to engineering, energy, and emerging technologies. Written and oral communication are stressed as a crucial component of professional and civic dialogue, while encouraging critical reading, thinking, and conversation about students' ethical obligations as world citizens with broader moral, social, and environmental responsibilities to stakeholders. The culminating research paper asks that students consider the ethical dimensions of their arguments within science and engineering contexts while engaging different viewpoints, evaluating sources, and supporting an original position. 3 hours seminar; 3 semester hours. Prerequisites: None. Corequisites: None.
Course Learning Outcomes

- 1. Demonstrate understanding of major ethical theories and concepts and apply them to current and past debates on technology, resource use, and environmental issues.
- 2. Read and think critically about course reading assignments and lecture topics; discover personal biases and values, diverse perspectives, and rhetorical strategies.
- 3. Construct original written and oral arguments about course topics that are supported by relevant experts and accurately cited evidence.
- 4. Find and employ relevant research to writing assignments on engineering, ethics, and the environment; consistently and correctly cite use of sources in-text and in bibliographies.
- 5. Develop clear, readable, grammatical written work through a process of drafting and revision to produce strong summaries, analyses of texts, and researched arguments.
- 6. Demonstrate understanding of the impact of engineering and applied science in social, ethical, and environmental contexts.
- 7. Develop habits of mind while completing the coursework, such as curiosity, openness, engagement, creativity, persistence, responsibility, academic integrity, flexibility, and metacognition to help in a variety of learning contexts.

HASS101. ACADEMIC ENGLISH PROFICIENCY. 3.0 Semester Hrs.
Academic English Proficiency will help non-native English speakers understand and apply advanced reading and writing skills required for success at the university level. Working with content from a wide range of academic and professional disciplines, students will master advanced grammar, inference, analysis, and vocabulary. The course will teach students how to incorporate complex sentence structure, diverse clauses, and word forms to improve their composition abilities in multiple writing contexts. To support these components, students will also improve their reading fluency and comprehension through academic texts specifically chosen to engage English language learners. Content and coursework will promote critical thinking and responses in English. Overall, students will learn about the cultural expectations associated with academic writing in American universities.
Course Learning Outcomes

- 1. Construct and incorporate appropriate tenses and advanced grammar including, but not limited to, passive vs. active voice, subject-verb agreement, and conditional clauses 2. Understand American collegiate expectations and culture 3. Understand intellectual property and apply this concept to appropriate source citation 4. Accurately interpret oral and written information for research purposes 5. Integrate sources using reporting verbs and rhetorically correct vocabulary 6. Use adverbials, tense agreement and other linking techniques to improve cohesion in academic papers 7. Incorporate academic vocabulary and evaluate appropriate word choice and form 8. Read fluently and accurately by understanding inference and context

HASS111. NATURE AND HUMAN VALUES SHORT FORM. 2.0 Semester Hrs.
Nature and Human Values will focus on diverse views and critical questions concerning traditional and contemporary issues linking the quality of human life and Nature, and their interdependence. The course will examine various disciplinary and interdisciplinary approaches regarding two major questions: 1) How has Nature affected the quality of human life and the formulation of human values and ethics? (2) How have human actions, values, and ethics affected Nature? Themes will include professional ethics, environmental ethics, and ethics of justice. This course that will assess research skills and written argumentation and requires in-class discussion and written reflection on course content. Prerequisites: HASS110 or AP English score of 5.
Course Learning Outcomes

- 1. Identify and explain the historical, social, and cultural contexts that influence professions in science, technology, engineering, and mathematics and examine the impact of such work on social, environmental, and ethical systems
- 2. Identify issues key to the future of STEM fields such as equity, implicit bias, climate change, and environmental racism and discuss these issues in a professional context.
- 3. Analyze course reading assignments and lecture topics; (compare, contrast, and criticize); successfully interpret and demonstrate rhetorical strategies
- 4. Construct written and oral arguments about course topics that are supported by relevant experts and evidence
- 5. Find and employ relevant research to writing assignments; consistently cite use of sources in-text and in bibliographies

HASS125. BEGINNING DRAWING AND PAINTING. 1.0 Semester Hr.
This course is designed to be a friendly, practical introduction to drawing, painting, charcoal and mixed media approaches to creating art. In this class students learn basic approaches to creating visual art, which include color theory, composition, observation, and different kinds of subjects, e.g., landscape. The class is open to all skill levels, but is designed for beginners. Prerequisite: None. Co-requisite: None.
Course Learning Outcomes

- • Learn the basic elements of artistic compositions, e.g., sketching, color and value, shading and blending
- • Produce work using different media, e.g., pencil, charcoal, acrylic paint, found objects, paper, etc.
- • Incorporate/evaluate feedback and coaching
- • Articulate and justify artistic vision

HASS198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS200. GLOBAL STUDIES. 3.0 Semester Hrs.
Equivalent with LAIS200,SYGN200,
Part of the Mines core curriculum, following the first-year requirement of HASS 100 (Nature and Human Values). Modern scientists and engineers operate in an increasingly interconnected world. This course is designed to enhance student capacity to understand, appreciate, and critically analyze the global contexts in which they will live and work. Course material examines the modern world through specific thematic lenses, with an emphasis on the major patterns of cultural, political, and/or environmental change. Students will develop original analysis through comparative empirical research on diverse societies and regions, and will communicate this analysis orally and in writing. Prerequisite: HASS100. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Examine and critically assess major cultural, political, and/or environmental patterns in the emergence of the modern world, with an emphasis on analytical comparisons across diverse regions and societies.
- 2. Identify and evaluate relevant empirical evidence from selected fields of study, and create persuasive arguments linking this evidence to larger trends, concepts, and themes covered in class.
- 3. Articulate and defend persuasive arguments related to the above subject matter, orally and in writing.

HASS201. WORKSHOP FOUNDATIONS: THE ART AND CRAFT OF CREATIVE WRITING. 3.0 Semester Hrs.
Equivalent with LAIS201,
(WI) This course examines the major patterns of modern and contemporary written forms. Topics analyzed include poetics, prose and creative nonfiction, and the personal or lyric essay. Poetics will focus on writing from imagism to modernism to beat and hippy writing, up to contemporary and postmodern poetry. Prose writing will examine the development of the shorts story from inception to contemporary approaches. Analysis of historical trends and change will also serve as a basis for developing student writing habits and strategies. Over the course of the semester, these subjects will be addressed through seminars, readings, workshops, and in-class discussion and activities. Prerequisites: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS202. TECHNICAL COMMUNICATION. 3.0 Semester Hrs.
(I) Technical Communication introduces students to the written and oral communication of technical information, and prepares students for effective professional communication. The course covers workplace writing, such as memos, proposals, and reports, visual communication, best practices for layout and design, ethical practices in the workplace, multimodal communication technologies, and oral presentations. 3 hours lecture; 3 semester hours.

HASS220. INTRODUCTION TO PHILOSOPHY. 3.0 Semester Hrs.
Equivalent with LAIS220,
A general introduction to philosophy that explores historical and analytic traditions. Historical exploration may compare and contrast ancient and modern, rationalist and empiricist, European and Asian approaches to philosophy. Analytic exploration may consider such basic problems as the distinction between illusion and reality, the one and the many, the structure of knowledge, the existence of God, the nature of mind or self. Prerequisite: HASS 100. Corequisite: HASS 200. 3 hours lecture; 3 credit hours.

HASS221. INTRODUCTION TO RELIGIONS. 3.0 Semester Hrs.
Equivalent with LAIS221,
This course has two focuses. We will look at selected religions emphasizing their popular, institutional, and contemplative forms; these will be four or five of the most common religions: Hinduism, Buddhism, Judaism, Christianity, and/or Islam. The second point of the course focuses on how the Humanities and Social Sciences work. We will use methods from various disciplines to study religion-history of religions and religious thought, sociology, anthropology and ethnography, art history, study of myth, philosophy, analysis of religious texts and artifacts (both contemporary and historical), analysis of material culture and the role it plays in religion, and other disciplines and methodologies. We will look at the question of objectivity; is it possible to be objective? We will approach this methodological question using the concept ?standpoint.? For selected readings, films, and your own writings, we will analyze what the ?standpoint? is. Prerequisite: HASS 100. Corequisite: HASS 200. 3 hours lecture; 3 semester hours.

HASS226. BEGINNING CLASS PIANO AND FUNDAMENTALS OF MUSIC. 3.0 Semester Hrs.
Equivalent with LAIS226,
HASS 226 is a beginning keyboard class. Students will learn to read music, develop fundamental keyboard skills, grasp basic music theory and history concepts, and understand the communal nature of music through ensemble preparation and public performance. Assessment will be based on class participation, written exams, student reflection papers, written and aural homework assignments, and public performances in class. The course will be a recommended, but not required, prerequisite for HASS 326 (Music Theory) and HASS 328 (Basic Music Composition and Arranging). Prerequisite: HASS100. Corequisite: HASS 200. 3 hours lecture; 3 semester hours.

HASS227. BEGINNING ORCHESTRAL STRINGS AND FUNDAMENTALS OF MUSIC. 3.0 Semester Hrs.
HASS 227 is a beginning orchestral ensemble class. Students will learn to read music, develop fundamental playing skills on one of four instruments available (violin, viola, cello, or bass), grasp basic music theory and history concepts, and understand the communal nature of music through ensemble participation and public performance. Assessment will be based on in-class peer and instructor critique, written exams, daily journal assignments, written, aural, and playing homework assignments, and public performances in class. Prerequisite: HASS100. Co-requisite: HASS200.
Course Learning Outcomes

- a. Read music fluently in a limited range b. Develop fundamental applied playing skills on one of four instruments: violin, viola, cello, or bass c. Play with physical freedom and ease in order to avoid long-term pain or injury d. Understand basic music theory concepts related the the act of playing and the structure of notated music e. Recognize, notate, and play back aural patterns f. Be familiar with important historical events and figures for string instruments such as the evolution of the orchestra, formal classical Western music traditions, and a few folk traditions g. Confidently play with accuracy and precision as an individual and also in small and moderately sized groups

HASS286. GLOBAL POLITICS & SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS286,

This is a beginning- level course intended to familiarize students with the study of politics across societies. The method is comparative in that it approaches the task of studying the world's different political systems by contrasting and comparing them along different dimensions, and by seeking generalizations about them. The class focuses on cases, topics, and methodologies in American and comparative politics. The course is part of the Global Politics & Society Minor. 3 hours lecture; 3 semester hours. Prerequisite: HASS100. Co-requisite: HASS200.

Course Learning Outcomes

- No change

HASS298. SPECIAL TOPICS. 1-6 Semester Hr.

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS298. SPECIAL TOPICS. 6.0 Semester Hrs.

Equivalent with LAIS298B,

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS298. SPECIAL TOPICS. 6.0 Semester Hrs.

Equivalent with LAIS298C,

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS299. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS299. INDEPENDENT STUDY. 1-6 Semester Hr.

Equivalent with LAIS299B,

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS299. INDEPENDENT STUDY. 1-6 Semester Hr.

Equivalent with LAIS299C,

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS299. INDEPENDENT STUDY. 1-6 Semester Hr.

Equivalent with LAIS299D,

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS300. INTERMEDIATE FICTION. 3.0 Semester Hrs.

Equivalent with LAIS300,

Students will write weekly exercises and read their work for the pleasure and edification of the class. The midterm in this course will be the production of a short story. The final will consist of a completed, revised short story. The best of these works may be printed in a future collection. 3 hours lecture; 3 semester hours. Prerequisite: HASS100. Co-requisite: HASS200.

HASS301. INTERMEDIATE POETRY WRITING WORKSHOP. 3.0 Semester Hrs.

Equivalent with LAIS301,

This course focuses on reading and writing poetry and asks students to develop new approaches and skills that will translate into a public art. Students will learn many different poetic forms to compliment prosody, craft, lyric, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic craft tools, encourage the writing of literary poetry, and stimulate the development of the student's craft in poetry and compositional ability. The purpose of the course is to experience the literature and its place in a multicultural society, while students "try on" various styles and contexts in order to develop their own voice. Prerequisite: HASS100. Co-requisite: HASS200.

HASS302. FOUNDATIONS IN CREATIVE WRITING. 3.0 Semester Hrs.

This mid-level HASS course is a writing workshop for literary short fiction. Students will be asked to write two new pieces of short fiction while they are introduced to the major patterns of modern and contemporary masters of the story form, and students will be expected to show progress in their own approach to creative writing and creative cognition and revision. Students will peer-review and critique new works (and have their own work peer reviewed), using their new knowledge gained from discussion topics such as: contemporary literature versus genre fiction inquiries, new organizational approaches to fiction, plot, character, setting, and all the many aspects of craft in professional creative writing. Students will also examine the short story form from inception to contemporary approaches, focusing on clear and chronological narratives. Analysis of historical trends and change will also serve as a basis for developing student writing habits and strategies. Over the course of the semester, these subjects will be addressed through seminars discussion, readings, workshops, and in-class discussion and activities. the production of a short story. Prerequisite: HASS100, HASS200. Co-requisite: HASS303 or instructor approval.

Course Learning Outcomes

- • Possess a growing understanding of the development, and craft approaches, for narrative theory and their own fiction writing. • Expand skills in revision and editing. • Discuss the ways in which major movements have impacted the development of the short fiction form from Chekhov to contemporary masters. • Be able to think critically about contemporary short fiction and be able to analyze and review peer writing from this new perspective. • Understand and mimic organizational theory and principles of short fiction and be ready to apply those strategies in written communication in their professional roles. • Possess increased skills in academic research, creative inquiry, and analytical thought, developed in their own writing and in-class discussions. • Communicate effectively and efficiently in groups and in front of large audiences. • Apply these discovered writing and creative approaches to a number of different sub-genres and prepare a portfolio of revised work that demonstrates growth and ability.

HASS303. FOUNDATIONS: THE ART AND CRAFT OF THE CREATIVE WRITING WORKSHOP. 3.0 Semester Hrs.
This course examines the major patterns of modern and contemporary written forms. Topics analyzed include poetics, prose and creative nonfiction, and the personal or lyric essay. Poetics will focus on writing from imagism to modernism to beat and hippy writing, up to contemporary and postmodern poetry. Prose writing will examine the development of the shorts story from inception to contemporary approaches. Analysis of historical trends and change will also serve as a basis for developing student writing habits and strategies. Over the course of the semester, these subjects will be addressed through seminars, readings, workshops focused on new student writing, and in-class discussion and activities. Prerequisite: HASS100. Co-requisite: HASS200.
Course Learning Outcomes

HASS305. AMERICAN LITERATURE: COLONIAL PERIOD TO THE PRESENT. 3.0 Semester Hrs.
Equivalent with LAIS305,
This course offers an overview of American literature from the colonial period to the present. The texts of the class provide a context for examining the traditions that shape the American nation as a physical, cultural and historical space. As we read, we will focus on the relationships between community, landscape, history, and language in the American imagination. We will concentrate specifically on conceptions of the nation and national identity in relation to race, gender, and class difference. Authors may include: Rowlandson, Brown, Apess, Hawthorne, Douglass, Melville, Whitman, James, Stein, Eliot, Hemingway, Silko, and Auster. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS307. EXPLORATIONS IN COMPARATIVE LITERATURE. 3.0 Semester Hrs.
Equivalent with LAIS307,
This course examines major figures and themes in the modern literatures of Africa, the Caribbean, and Latin America. Reading, discussion and writing will focus on fiction and poetry representing Francophone, Arabic, and Hispanophone traditions within these world regions. Engaging these texts will foster understanding of some of the pivotal philosophical, political, and aesthetic debates that have informed cultural practices in diverse colonial territories and nation-states. Thematic and stylistic concerns will include imperialism, nationalism, existentialism, Orientalism, negritude, and social and magical realisms. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS309. LITERATURE AND SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS309,
Before the emergence of sociology as a distinct field of study, literary artists had long been investigating the seemingly infinite complexity of human societies, seeking to comprehend the forces shaping collective identities, socio-cultural transformations, technological innovations, and political conflicts. Designed to enrich recognition and understanding of the complex interplay of artistic creativity and social inquiry over time, this course compares influential literary and social-scientific responses to the Enlightenment, the Industrial Revolution, and other dynamic junctures integral to the forging of "modernity" and the volatile world we inhabit today. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS314. INTRODUCTION TO THEATRICAL IMPROVISATION. 3.0 Semester Hrs.
This course is designed to advance students? comic, improvisational and ensemble acting skills as well as offering instruction in solo and group comedic material developed from improvisation. The course will culminate in a public performance of the material generated in class. Prerequisite: HASS100, HASS200.
Course Learning Outcomes

- Upon successful completion of this course, a student will be able to:

HASS315. MUSICAL TRADITIONS OF THE WESTERN WORLD. 3.0 Semester Hrs.
Equivalent with LAIS315,
An introduction to music of the Western world from its beginnings to the present. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS316. JAZZ AND AMERICAN POPULAR MUSIC. 3.0 Semester Hrs.
This upper-level HASS course explores the American musical style called Jazz, as well as examining the evolution and development of popular music in America. The shared history, background, differences and similarities of these artistic areas will be examined for a deeper understanding of the impact they had in the modern world. Topics analyzed include: regional influences, evolution in thematic material, technological development, important artistic contributions, political and societal factors, and music as a product vs an art form. Analysis of historical trends and change will also serve as a framework for student opinions. Over the course of the semester, these subjects will be addressed through lectures, seminars, readings, and in-class discussion and activities. Students will develop their own analytical skills, which will be demonstrated in written opinion responses, in-class discussions, and musical analysis projects. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Understand techniques and vocabulary common in the musical world. 2. Understand, analyze, and explain song form, rhyme structure, and genre idiosyncrasies in jazz and popular musical styles (i.e.Bebop, Swing, Funk, Southern Rock, etc.). 3. Demonstrate proficiency in recognizing key elements in contemporary music. 4. Explain the impact of political, societal, and cultural change and evolution on contemporary musical styles. 5. Think critically about the subjective vs. objective qualities of current musical performances, styles, trends, and products. 6. Demonstrate an understanding of the impact of technological change in the music industry. 7. Actively listen and analyze music of multiple styles, recognizing the traditions, historical practices, and posible future trends of those styles.

HASS317. ACTING, LOCUTION & PUBLIC PERFORMANCE. 3.0 Semester Hrs.
This upper-level HASS course focuses on locution, public speaking and acting through realism. Students will gain the confidence and exposure to present to a large audience. Improvisation, Character Work, Presentation, Monologue and Scene Work are the focus of this class.
Course Learning Outcomes

- Through individual and group exercises, improvisations, monologues and scene studies, this class, eclectic in method, helps students develop their acting potential and sharpen their skills in interpreting scripts. Previous theatre study is not required.

HASS318. THEATER TECHNOLOGY, PRODUCTION & PERFORMANCE. 3.0 Semester Hrs.
This course is intended to give students a well-rounded and developed foundation in theatrical scenery, props, lighting, sound, and costuming,

which will then be transferred into a final performance, showcasing the pathway of engineering technology into performance.

Course Learning Outcomes

- 1. Upon completion of the course, the student should understand Theatre Production basics coupled with an Engineering concept as a base. The student will receive a foundation of the stage and its equipment, theatre safety issues, tools and materials used and an idea of the design process. 2. With a focus of design, group planning and group work, the student will acquire the skills to perform basic construction for scenery and props and the knowledge to assist with implementing lighting and sound designs. 3. Historical traditions and practices of theatre will also be included throughout the course of the semester.

HASS319. INTRODUCTION TO VOICE, MOVEMENT AND IMPROVISATION IN PERFORMANCE AND PRESENTATION. 3.0 Semester Hrs.

The class will cover techniques drawn from a wide variety of voice and movement philosophies including Linklater, Suzuki, Grotowski, Alexander, yoga, and others.

Course Learning Outcomes

- 1. This class will introduce students to a range of vocal and physical techniques for creative expression in performance. 2. Through a series of exercises, trainings, and performances, students will have the opportunity to reduce habitual tensions, connect their movement and voice to imagery and text, and increase the strength, flexibility, and dynamic of their voices and bodies in performance.

HASS320. ETHICS. 3.0 Semester Hrs.

Equivalent with LAIS320,

A general introduction to ethics that explores its analytic and historical traditions. Reference will commonly be made to one or more significant texts by such moral philosophers as Plato, Aristotle, Augustine, Thomas Aquinas, Kant, John Stuart Mill, and others. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS323. INTRODUCTION TO SCIENCE COMMUNICATION. 3.0 Semester Hrs.

Equivalent with LAIS323,

This course will explore the relationship between science and the public through an examination of science writing and communication on current events. Students will study various forms of science communication, including essays, blogs, news segments, media clips, and radio programs in order to understand the ways in which science is communicated beyond the lab or university and into the public consciousness. Science writing often explores the human condition, reflects on hopes and worries about technology, and informs our collective knowledge about the world. Students will discuss the implications of this kind of communication, analyze breakdowns in communication through case studies, and write for peer and popular audiences, including turning a lab report into a short feature article and writing a science essay. Prerequisite: HASS100. Corequisite HASS200. 3 hours lecture; 3 semester hours.

HASS324. AUDIO/ACOUSTICAL ENGINEERING AND SCIENCE. 3.0 Semester Hrs.

Equivalent with LAIS324,

Audio/acoustical engineering and science teaches concepts surrounding the production, transmission, manipulation and reception of audible sound. These factors play a role in many diverse areas such as the design of modern music technology products, recording studios and loudspeakers, civil engineering and building design, and industrial safety. This course will explore and concepts of this field and the physics/mechanics that are involved, as well as aesthetic impacts related to the subject matter. Discussion of human anatomy and psycho acoustic phenomena are also presented. 3 hours lecture; 3 semester hours. Prerequisite: HASS100. Co-requisite: HASS200.

HASS326. MUSIC THEORY. 3.0 Semester Hrs.

Equivalent with LAIS326,

The course begins with the fundamentals of music theory and moves into more complex applications. Music of the common practice period (18th century) and beyond is considered. Aural and visual recognition of harmonic material is emphasized. 3 hours lecture; 3 semester hours. Prerequisite: HASS100. Co-requisite: HASS200.

HASS327. MUSIC TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with LAIS327,

An introduction to the physics of music and sound. The history of music technology from wax tubes to synthesizers. Construction of instruments and studio. 3 hours lecture; 3 semester hours. Prerequisite: HASS100. Co-requisite: HASS200.

HASS328. BASIC MUSIC COMPOSITION AND ARRANGING. 1.0 Semester Hr.

Equivalent with LAIS328,

This course begins with the fundamentals of music composition and works towards basic vocal and instrumental arrangement skills. Upon completion of this course the student should: 1) Demonstrate basic knowledge of (music) compositional techniques; 2) Demonstrate primary concepts of vocal and instrumental ensemble arrangement; 3) Demonstrate an ability to use notational software and Midi station hardware. Repeatable for credit. 1 hour lecture; 1 semester hour. Prerequisite: HASS100. Co-requisite: HASS200.

HASS329. REEVALUATION OF DESIGN AND SUSTAINABLE FUTURE OF MUSICAL INSTRUMENT. 3.0 Semester Hrs.

History of musical instruments will be surveyed with the particular emphasis on their evolution of designs, materials, and engineering. Musical instrument of choice will be built by each small group of students reflecting their own solution to current design issues identified through their research. Special consideration will be given to sustainable materials, including finishes, and new engineering ideas. Prerequisite: HASS 100. Co-requisite: HASS 200.

Course Learning Outcomes

- Students should

HASS330. MUSIC TECHNOLOGY CAPSTONE. 3.0 Semester Hrs.

Equivalent with LAIS330,

Project-based course designed to develop practical technological and communication skills for direct application to the music recording. 3 hours lecture; 3 semester hours. Prerequisite: EDNS191 or HASS100 or LAIS100 or HNRS105, HNRS115 or CSM191, CSM192, HASS327. Co-requisite: EDNS29, HASS200, LAIS200, HNRS315, SYGN200.

HASS339. MIDDLE EAST: POLITICS & SOCIETY. 3.0 Semester Hrs.

Equivalent with LAIS339,

(WI) A broad survey of the interrelationships between the state and market in the Middle East as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics between the developed North and the developing South. 3 hours lecture; 3 semester hours. Prerequisite: HASS100. Co-requisite: HASS200.

Course Learning Outcomes

- no change

HASS344. INTERNATIONAL RELATIONS. 3.0 Semester Hrs.
Equivalent with LAIS344,
This course surveys major topics and theories of international relations. Students will evaluate diverse perspectives and examine a variety of topics including war and peace, economic globalization, human rights and international law, international environmental issues, and the role of the US as the current superpower. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS360. RESEARCH, VALUES, AND COMMUNICATION. 3.0 Semester Hrs.
This 3-credit class, which is one of the HASS electives, helps students prepare to be effective in research in science or engineering, for communicating research to an intended audience, and for developing ethical standards that are grounded in personal values. The class covers elements of doing research, such as choosing a research topic, generating research questions, making a work plan, dealing with the ambiguity and hurdles of research, research ethics, broader social and ethical impacts of research, as well as publishing scientific papers, scientific writing, giving oral communications, and writing research proposals. Students acquire hands-on experience by choosing a research project, performing a literature search, develop critical thinking, making a work plan, writing a proposal, and presenting that proposal. The proposal can be the upbeat to a senior design project.
Course Learning Outcomes

- 1. Describe the challenges and opportunities in carrying out research, creating SMART goals, ethical conduct of research, and identifying strategies for optimizing the research experience.
- 2. Communicate proposed research professionally by writing an introduction, a plan for execution of the research, the broader social and ethical impacts of the research, and a bibliography for a research proposal to a potential sponsor.
- 3. Generate research questions with at least 4 techniques and use the questions to construct a workplan using creativity-enhancing software for a research project.
- 4. Demonstrate how to communicate effectively with oral presentations, written work, and posters/slide design, while adapting to the appropriate tone and detail for the intended audience.
- 5. Clarify personal values and explain how these values affect everyday life, professional practice, and the choice of future career goals.
- 6. Apply practical ethics tool(s) (e.g., professional ethical codes, three ethical theories, Davis's Seven Step Guide) and personal values to analyze professional ethics cases.

HASS365. HISTORY OF WAR. 3.0 Semester Hrs.
Equivalent with LAIS365,
History of War looks at war primarily as a significant human activity in the history of the Western World since the times of Greece and Rome to the present. The causes, strategies, results, and costs of various wars will be covered, with considerable focus on important military and political leaders as well as on noted historians and theoreticians. The course is primarily a lecture course with possible group and individual presentations as class size permits. Tests will be both objective and essay types. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS366. DIVIDED STATES OF AMERICA. 3.0 Semester Hrs.
This course explores the historical underpinnings of contested developments in recent U.S. history. Students will learn about various social movements, economic changes, and political developments that have created fractures in contemporary American society. Through readings, writings, and discussions, students will develop analytical tools for identifying and assessing differing economic, political, environmental, and social contexts within the United States. The course further emphasizes the application of critical skills for assessing conflicting evidence and interpretations. Topics include economic growth and change, government power and policy, social movements across the political spectrum, wars and international relations, political parties and movements, and racial, class, gender, regional, and religious influences on American life. Prerequisite: HASS100. Co-requisite: HASS200 (although HASS200 can also be taken as a pre-requisite).
Course Learning Outcomes

- 1. Recall major political, social, and cultural events in the history of the United States from 1890s to the present, including the major divisions and conflicts that have shaped our contemporary environment -- THUS developing student understanding of the societal context in which they work and live and enhancing their knowledge of contemporary issues.
- 2. Analyze major paradigms for interpreting U.S. history, including structure vs. contingency, economic vs. political, continuity vs. aberration, social vs. political, realism vs. idealism - THUS developing student capacity to analyze societal happenings past and present
- 3. Identify and articulate ways in which historical and contemporary experience differs according to race, class, gender, geographic, and religious identities – THUS developing student empathy and knowledge of divergent community experiences, traditions, and needs
- 4. Summarize accurately, and evaluate critically, competing historical arguments and evidence -- THUS developing student ability to read critically and assess complex and contradictory data
- 5. Construct and communicate persuasive evidence-based historical arguments that assess, critique, and synthesize the interpretations and evidence of two major and contrasting interpretations of U.S. history -- THUS developing student higher-level analytical skills and comprehension of American life
- 6. Apply claim, data, justification model to communication of original argument at paragraph & essays levels -- THUS developing the capacity to organize logically information & arguments
- 7. Cite varying forms of primary & secondary evidence using discipline-specific style -- THUS developing the ability to research & apply conventions from other disciplines and professional contexts
- 8. Create visual and audio-visual representations of historical arguments and developments – THUS developing student capacity to apply knowledge in multiple communication contexts

HASS370. HISTORY OF SCIENCE. 3.0 Semester Hrs.
Equivalent with LAIS370,
An introduction to the social history of science, exploring significant people, theories, and social practices in science, with special attention to the histories of physics, chemistry, earth sciences, ecology, and biology. Prerequisite: HASS100. Corequisite HASS200. 3 hours lecture; 3 semester hours.

HASS372. HISTORY OF MEDICINE. 3.0 Semester Hrs.
This class explores the history of western medicine from antiquity to modernity, examining both how western ideas about the causes and cures of human ailments have changed overtime, how culture and society informed these ideas, and how disease has shaped human history. In addition to this, topics to be covered include how the medical profession and identity of medical professionals evolved overtime, the histories of

psychiatry, hospitals, surgery, public health, and tropical medicine, and how medicine intersects with power and discrimination.

Course Learning Outcomes

- 1) Understand the history of medicine from antiquity to the late twentieth century 2) Understand how culture informs medicine and medicine informs culture 3) Understand how disease has shaped human history, including social and economic structures, religion and culture, and relationship between citizens and the state. 4) Analyze primary sources, and use them to construct historical arguments 5) Conduct historical research using primary and secondary sources and write a research essay that adheres to the disciplinary conventions of history. 6) Craft and deliver strong oral presentations

HASS376. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.

Equivalent with LAIS376,

Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student's learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: HASS100. Co-requisite: HASS200.

HASS398. SPECIAL TOPICS. 1-6 Semester Hr.

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS398. SPECIAL TOPICS. 1-6 Semester Hr.

Equivalent with LAIS398B,

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS398. SPECIAL TOPICS. 1-6 Semester Hr.

Equivalent with LAIS398C,

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS398. SPECIAL TOPICS. 1-6 Semester Hr.

Equivalent with LAIS398D,

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.

Equivalent with LAIS399B,

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.

Equivalent with LAIS399C,

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.

Equivalent with LAIS399D,

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.

Equivalent with LAIS399E,

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS400. ADVANCED SHORT FICTION WRITING WORKSHOP. 3.0 Semester Hrs.

(WI) This upper-level HASS course examines the major patterns of modern and contemporary written forms of fiction, and asks students to apply what they learn in their own writing. Topics analyzed include: prose and narrative theory, organizational approaches to fiction, plot, character, setting, and all the many aspects of professional creative writing. Critical prose writing by the students will examine the development of the short story from inception to contemporary approaches. Analysis of historical trends and change will also serve as a basis for developing student writing habits and strategies. Over the course of the semester, these subjects will be addressed through seminars, readings, workshops, and in-class discussion and activities. Students will advance their own literary fiction-writing skills, which will be demonstrated in two new short stories over the course of the semester, and will turn in a final portfolio and critical paper to show their growth. Prerequisite: HASS100. Co-requisite: HASS200, HASS300, HASS302 or instructor consent.

Course Learning Outcomes

- After successful completion of this course, students will: # Possess an advanced understanding of the development and craft approaches for narrative theory in order to produce publishable fiction writing. # Expand and master skills in advanced professional revision and editing. # Understand the ways in which major movements have impacted the development of the short fiction form, and critically inquire into how these work in the form. # Think critically and deeply about contemporary short fiction in order to analyze and review peer writing from this new perspective. # Apply organizational theory and principles to short fiction, and apply those strategies in written communication in their professional roles. # Communicate effectively and efficiently in groups and in front of large audiences. # Apply these advanced writing and creative approaches to a number of different sub-genres, and prepare a publishable final chapbook that demonstrates growth and ability.

HASS401. ADVANCED POETRY WRITING WORKSHOP. 3.0 Semester Hrs.

Equivalent with LAIS401,

This course is a continuation of HASS 301 for those interested in developing their poetry writing further. It focuses on reading and writing poetry and creating a final project tied to literary reviews or portfolios. Students will learn many different poetic forms to compliment prosody, craft, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic tools, encourage the writing of literary poetry, and simulate the development of the student's craft. The purpose of the course is to experience the literature and its place in a multicultural society, while students "try on" various styles and contexts in order to develop their own voice. Prerequisite: HASS100. Co-requisite: HASS200, HASS301 or Instructor Consent.

HASS404. WOMEN, LITERATURE, AND SOCIETY. 3.0 Semester Hrs.

Equivalent with LAIS404,

This reading and writing intensive course examines the role that women writers have played in a range of literary traditions. Far from residing in the margins of key national debates, women writers have actively contributed their voices to demands for social, racial, economic, and artistic equality. We will examine the writing produced by women from a diversity of racial, ethnic, and social backgrounds, as we examine the ways in which women writers respond to the various pressures placed on them as artists and activists. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS406. THE LITERATURE OF WAR AND REMEMBRANCE. 3.0 Semester Hrs.

Equivalent with LAIS406,

In "The Literature of War and Remembrance," students survey poetry, prose, and film ranging from classicial to contemporary war literature. The course considers literary depictions of the individual and society in war and its aftermath. Critical reading and writing skills are demonstrated in creative presentations and analytical essays. Students will investigate war literature and commemorative art inspired by recent world conflicts, and place a contemporary work into the thematic structure of the course. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS407. SCIENCE IN LITERATURE. 3.0 Semester Hrs.

Equivalent with LAIS407,

Science fiction often serves as a cautionary tale that deals with the darker side of humanity's desires in order to find a better understanding of who we are and what we hope to become. This class examines scientific and social progress as it is imagined by some of the greatest authors of the genre. We will examine the current events that may have influenced the writing and position our lens to the scientific and technological breakthroughs, as well as the social, cultural, and political state of the world at the time of our readings. This course focuses on classic science fiction from the late 1800's to the present which may include: Jules Verne, H.G. Wells, Sir Arthur Conan Doyle, Jack Williamson, Isaac Asimov, Robert Heinlein, Alfred Bester, Philip Jose Farmer, Marion Zimmer Bradley, Ray Bradbury, Philip K. Dick, William Gibson, Arthur C. Clarke, Ursula K. LeGuin and Mary Doria Russell, among others. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS408. CREATIVE NONFICTION WRITING: LIFE STORIES. 3.0 Semester Hrs.

Equivalent with LAIS408,

Using texts by published contemporary authors we will explore the pleasures and challenges of creating and interpreting narratives based on "real life." The class will consider critical theories about the relationship between the self and the stories we tell and the focus of this course will be on the workshop model where students will create new written work that will be presented for written and oral critique. Prerequisite: HASS100. Co-requisite: HASS200.

HASS410. CRITICAL PERSPECTIVES ON 20TH CENTURY LITERATURE. 3.0 Semester Hrs.

Equivalent with LAIS410,

This course introduces students to texts and cultural productions of the 20th Century literature. We will examine a diverse collection of materials, including novels and short stories, poems, plays, films, painting, and sculpture. Science, technology, violence, history, identity, language all come under the careful scrutiny of the authors we will discuss in this course, which may include Conrad, Fanon, Achebe, Eliot, Kafka, Barnes, Camus, Borges, and Marquez, among others. We will also screen films that comment upon the fragility of individual identity in the face of modern technology. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS411. LITERATURES OF THE AFRICAN WORLD. 3.0 Semester Hrs.

Equivalent with LAIS411,

This course examines wide-ranging writers' depictions of collective transformations and conflicts integral to the making and remaking of African and Afro-diasporic communities worldwide. Fiction, poetry, and essays representing diverse linguistic, aesthetic, and philosophical traditions will constitute the bulk of the reading. Alongside their intrinsic expressive values, these texts illuminate religious and popular cultural practices important to social groups throughout much of sub-Saharan Africa, the Caribbean, Latin America, and the United States. Primary socio-historical themes may include the slave trade, plantation cultures, generational consciousness, ethnicity, gender relations, urbanization, and collective violence. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS412. LITERATURE AND THE ENVIRONMENT. 3.0 Semester Hrs.

Equivalent with LAIS412,

This reading and writing intensive course investigates the human connection to the environment in a broad range of literary materials. Discussions focus on the role of place - of landscape as physical, cultural, moral, historical space - and on the relationship between landscape and community, history, and language in the environmental imagination. Readings include texts that celebrate the natural world, those that indict the careless use of land and resources, and those that predict and depict the consequences of that carelessness. Additionally, we investigate philosophical, legal, and policy frameworks that shape approaches to environmental issues. Prerequisite: HASS100. Corequesite HASS200. 3 hours seminar; 3 semester hours.

HASS413. ENVIRONMENTAL FILM. 3.0 Semester Hrs.

This class explores the ways in which films convey competing narratives about the relationship between humans and the environment. Students will learn to analyze and interpret visual culture in order to understand how cinematic narratives have shaped our societal understandings of the so-called "natural" world and our engagement with energy sources. By examining competing stories that embed different messages about what audiences should think, feel, and do in order to balance energy needs against environmental crises, students in the class will be able to answer the following questions: In what ways are terms like "nature" and the "environment" constructed, and how do these constructions substantively change not only environmental imaginaries but the lived experience of global citizens? How have the cultural and historical contexts in which environmental discourses have been produced affected the production and reception of those narratives and the people who perpetuate them? How do representations of the environment and energy on film impact popular opinions and inflect the ways in which we are able to communicate politically on individual, national, and global scales? This class explores the ways in which films convey competing narratives about the relationship between humans and the environment. Prerequisites: HASS100. Corequisites: HASS200.

Course Learning Outcomes

- 1. Identify major events, themes, and concepts that have shaped the modern American environmental movement
- 2. Successfully utilize environmental studies methodology.
- 3. Write cogent essays that make strong and logical arguments using primary and secondary sources
- 4. Analyze various scholarly debates about visual culture and the politics of environmental narratives

HASS415. MASS MEDIA STUDIES. 3.0 Semester Hrs.

Equivalent with LAIS415,

This introduction to mass media studies is designed to help students become more active interpreters of mass media messages, primarily those that emanate from television, radio, the Internet, sound recordings (music), and motions pictures (film, documentary, etc.). Taking a broad rhetorical and sociological perspective, the course examines a range of mass media topics and issues. Students should complete this course with enhanced rhetorical and sociological understandings of how media shapes individuals, societies, and cultures as well as how those groups shape the media. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS416. FILM STUDIES. 3.0 Semester Hrs.

Equivalent with LAIS416,

This course introduces students to the basics of film history, form, and criticism. Students will be exposed to a variety of film forms, including documentary, narrative, and formalist films, and will be encouraged to discuss and write about these forms using critical film language. Students will have an opportunity to work on their own film projects and to conduct research into the relationship between films and their historical, cultural, and ideological origins. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS417. INDIGENOUS LITERATURE. 3.0 Semester Hrs.

This course will investigate indigenous literature in formerly colonized countries and ways in which indigenous peoples around the world survive, adapt, and even thrive in contemporary contexts. From the Arctic to the South Pacific, indigenous people possess unique languages, stories, and belief systems and a valuable understanding of sustainability practices. Reading literature by indigenous writers from North and South America, Australia, New Zealand, African and Asian nations, students will delve into identity issues; land dispossession; assimilation; gender and class; social and environmental justice; tribal identity and city life among other themes. Prerequisite: HASS100, HASS200.

Course Learning Outcomes

- • Read and think critically about course readings and lecture topics focused on indigenous literature.
- • Investigate the historical, cultural, social, and political contexts within which indigenous literary works emerge.
- • Develop an understanding of the literature and experiences of different indigenous groups, including the relationship between indigenous and settler culture and literature.
- • Construct written and oral arguments about course topics that are supported by relevant experts and evidence.
- • Develop written work through a process of drafting and revision to produce clear analyses of texts.
- • Find and employ relevant research to writing assignments; consistently cite use of sources in-text and in bibliographies.

HASS418. NARRATING THE NATION. 3.0 Semester Hrs.

Equivalent with LAIS418,

The novel, nationalism, and the modern nation-state share the same eighteenth and nineteenth-century roots. Relationships between the works of novelists, local nationalisms, and state politics have, however, always been volatile. These tensions have assumed particularly dramatic expressive and political forms in Latin America and postcolonial South Asia and Africa. This course examines the inspirations, stakes, and ramifications of celebrated novelists' explorations of the conflicted and fragmentary character their own and/or neighboring nationstates. Beyond their intrinsic literary values, these texts illuminate distinctive religious, ritual, and popular cultural practices that have shaped collective imaginings of the nation, as well as oscillations in nationalist sentiment across specific regions and historical junctures. Studies in relevant visual media -films, paintings, and telenovelas - will further our comparative inquiry into the relationships between artistic narrative and critical perspectives on "the nation." Alongside the focal literary and visual texts, the course will address major historians' and social theorists' accounts of the origins, spread, and varied careers of nationalist thought and practice across our modern world. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS419. ENVIRONMENTAL COMMUNICATION. 3.0 Semester Hrs.

Equivalent with LAIS419,

(WI) This course explores the ways that messages about the environment and environmentalism are communicated in the mass media, fine arts, and popular culture. The course will introduce students to key readings in environmental communication, media studies, and cultural studies in order to understand the many ways in which the images, messages, and politics of environmentalism and the natural world are constructed and contested. Students will critically analyze their roles as science and/or technology communicators in the context of environmental issues and will apply their skills to creating communications projects for diverse audiences. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Identify major events, themes, and concepts, and narratives that have shaped the modern environmental movement and societal understandings of environmentalism
- Analyze environmental debates in both academic discourse and popular culture
- Understand and engage critically with the roles that scientists and engineers play as communicators in environmental debates

- Research and develop professional written products that make strong and logical arguments using primary and secondary sources
- Sharpen oral communication and presentation skills

HASS421. ENVIRONMENTAL PHILOSOPHY AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS421,
A critical examination of environmental ethics and the philosophical theories on which they depend. Topics may include preservation/conservation, animal welfare, deep ecology, the land ethic, eco-feminism, environmental justice, sustainability, or non-western approaches. This class may also include analyses of select, contemporary environmental issues. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS422. ART AND ENVIRONMENTALISM. 3.0 Semester Hrs.
This course introduces students to the basics of art history and criticism with a focus on how environmental philosophies manifest in works of art. Students will be exposed to a variety of art forms, including painting, photography, and sculpture, and will be encouraged to discuss and write about these forms using the language of visual analysis. Students will have an opportunity to work on their own art projects and to conduct research into the relationship between art objects and their historical, cultural, and ideological origins. Prerequisite: HASS200.
Course Learning Outcomes

- 1. Identify major events, themes, and concepts that have shaped art history 2. Understand how art has both reflected and helped to shape the relationship between human beings and the “natural world” 3, Analyze and interpret visual culture 4. Identify how art and culture interact 5. Analyze various scholarly debates about visual culture and the politics of narrative 6. Write cogent essays that make strong and logical arguments using primary and secondary sources 7. Understand how art and engineering intersect

HASS423. ADVANCED SCIENCE COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS423,
This course will examine historical and contemporary case studies in which science communication (or miscommunication) played key roles in shaping policy outcomes and/or public perceptions. Examples of cases might include the recent controversies over hacked climate science emails, nuclear power plant siting controversies, or discussions of ethics in classic environmental cases, such as the Dioxin pollution case. Students will study, analyze, and write about science communication and policy theories related to scientific uncertainty; the role of the scientist as communicator; and media ethics. Students will also be exposed to a number of strategies for managing their encounters with the media, as well as tools for assessing their communication responsibilities and capacities. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS425. INTERCULTURAL COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS425,
The course examines intercultural communication theory and practice. In particular, the course provides students with a window into how intercultural (mis)communication cases arise, evolve, and are resolved. Students investigate communication cases and issues across a broad range of cultural divides, such as national, ethnic, gender, and social class cultures. Some case studies are situated in engineering and applied science contexts. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS427. RISK COMMUNICATION. 3.0 Semester Hrs.
How do people perceive risk, as well as make decisions and communicate under conditions of uncertainty and risk? This course explores multiple perspectives on that overarching question. Although risk perception, risk management, and risk communication are three major course components, they are not treated separately but in terms of how they interrelate. Case studies include engineers and applied scientists coping with complex forms of uncertainty and risk, communicating in organizational and public sphere contexts with multiple audiences via the press and directly to the public, stockholders, co-workers, local communities, and more. In addition, students will critically reflect on the social consequences of living with risk in our contemporary moment. Prerequisite: HASS100. Co-requisite: HASS200.
Course Learning Outcomes

- a) applying the following dimensions of risk analysis: hazard identification, probability analysis, potential consequences, identifying mitigation strategies, cultivating resiliency, and designing communication.
- b) analyzing contemporary case studies of risk and crisis messaging as they pertain to industrial processes, environmental hazards, and public safety.
- c) taking account of their own personally and culturally derived dispositions towards risk in professional and civic contexts.
- d) utilizing experiential scenarios to illuminate the lived experience of risk perception, protective action, and precautionary discourse.

HASS429. REAL WORLD RECORDING/RESEARCH. 3.0 Semester Hrs.
Equivalent with LAIS429,
(WI) This reading and writing-intensive course explores the acoustical, musical, and technical aspects of recording a variety of live ethno-musicological music genres and/or performances, towards the purpose of learning how to research, document and capture the most accurate and authentic recording. Historical research, non-traditional recording techniques; archival documentation, and editing will all be a part of this course. Prerequisites: HASS100 and HASS315 or HASS327. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS430. PSYCHOLOGY FOR ENGINEERING. 3.0 Semester Hrs.
A general introduction to psychology with a focus on how it relates to technology, engineering, and computing. We will explore the general psychological lenses through which human thoughts, feelings, and behavior are studied and understood including behavioral, cognitive, developmental, humanistic, and social perspectives. Students will learn how psychological principles and knowledge can be applied to investigate and solve real-world problems such as how to make technology more inviting, reliable, useful, and safe. Gaining a better understanding of how humans think, feel, and behave can also be useful in our personal lives, thus this course will also focus on supporting students in navigating their own environments and careers by examining meaningful topics such as human learning and development, motivation, stress and health, and personality and society. Prerequisite: HASS 100 (NHV) and HASS 200 (Global Studies) Co-requisite: HASS 200 (Global Studies).
Course Learning Outcomes

- • Contextual Appreciation: Understand the history of psychology theory and research and its perpetual interplay in the history and development of other science, engineering, and computing developments

HASS431. MORAL PSYCHOLOGY, RELIGION, AND AMERICAN SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS431,
(WI) This course introduces intersections of moral psychology, religion in American society. Course begins with an understanding of religion in the United States and how religion has influenced foreign affairs throughout history (national security). Course introduces insights from moral psychology to shed light on the political spectrum in American political life. The course then explores how faith-based organizations make decisions on when and how to enter American political life for social change (intrasecurity). Finally, the course explores the connections between religion and terrorism that have seen some rise in the early 21st century (national security). Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- • Define and trace the development of religious expression in the United States from its founding to current trends in American society in the 21st century
- • Describe and identify the major historical periods in American foreign relations
- • Articulate major arguments of how moral psychology explains the political differences between liberals and conservatives in the United States since the 1960s
- • Compare and contrast theological perspectives that explain how and when religiously-based organizations directly engage in politics and society to impact social change
- • Classify the major causes of the linkages between religious motivation in terrorist organizations, groups, and individuals
- • Formulate and argue in a major research paper, how religion and/or moral psychology can shed light on United States foreign policy and national security
- • Formulate, in a group presentation on a case study, a counter-terrorism national security memo to the President of the United States

HASS432. ROBOT ETHICS. 3.0 Semester Hrs.
This course explores ethical issues arising in robotics and human-robot interaction through philosophical analysis, behavioral and psychological analysis, research ethics education, and the integration of social and ethical concerns in scientific experimentation and algorithm design. Topics include case studies in lethal autonomous weapon systems, autonomous cars, and social robots, as well as higher-level concerns including economics, law, policy, and discrimination. Prerequisite: HASS200.
Course Learning Outcomes

- Understand the basic ethical theories, concepts, tools, and frameworks for analyzing the social and ethical ramifications of robotics
- Be able to critically examine the ethical significance of the use of robotics in daily and technical fields including human-robot interaction, medicine, relationship, military, etc.
- Develop a critical attitude toward the role of robotics in shaping human society including human perceptions and behaviors
- Be able to use the theories, concepts, tools, and frameworks learned from this class to critically examine emerging robot ethics issues in the society

HASS433. SHAKESPEARE AND THE SCIENTIFIC REVOLUTION. 3.0 Semester Hrs.
Equivalent with LAIS433,
(WI) This course investigates ways in which William Shakespeare, a contemporary of Galileo, reflects in his work scientific theories and discoveries emerging during the Renaissance that transformed long-held world views. Shakespeare presents characters encountering unprecedented challenges interpreting their own relationship to the natural world and the political world, the spiritual world and the New World, the world of arts and the human imagination. Because the Renaissance concept of science is so broad and multi-disciplinary, students will be able to pursue individual interests in their research for this course. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS435. LATIN AMERICAN DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS435,
A seminar designed to explore the political economy of current and recent past development strategies, models, efforts, and issues in Latin America, one of the most dynamic regions of the world today. Development is understood to be a nonlinear, complex set of processes involving political, economic, social, cultural, and environmental factors whose ultimate goal is to improve the quality of life for individuals. The role of both the state and the market in development processes will be examined. Topics to be covered will vary as changing realities dictate but will be drawn from such subjects as inequality of income distribution; the role of education and health care; region-markets; the impact of globalization, institution-building, corporate-community-state interfaces, neoliberalism, privatization, democracy, and public policy formulation as it relates to development goals. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS437. ASIAN DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS437,
This international political economy seminar deals with the historical development of Asia Pacific from agrarian to post-industrial eras; its economic, political, and cultural transformation since World War II, contemporary security issues that both divide and unite the region; and globalization processes that encourage Asia Pacific to forge a single trading bloc. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS439. MIDDLE EAST DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS439,
This internationa political economy seminar analyzes economic, political and social dynamics that affect the progress and direction of states, markets, and peoples of the region. It examines the development of the Middle East from agrarian to post-industrial societies; economic, political and cultural transformations since World War II; contemporary security issues that both divide and unite the region; and the effects of globalization processes on economies and societies in the Middle East. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS441. AFRICAN DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS441,
This course provides a broad overview of the political economy of Africa. Its goal is to give students an understanding of the possibilities of African development and the impediments that currently block its economic growth. Despite substantial natural resources, mineral reserves, and human capital, most African countries remain mired in poverty. The struggles that have arisen on the continent have fostered thinking about the curse of natural resources where countries with oil or diamonds are beset with political instability and warfare. Readings give first an introduction to the continent followed by a focus on the specific issues that confront African development today. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS448. GLOBAL ENVIRONMENTAL ISSUES. 3.0 Semester Hrs.
Equivalent with LAIS448,
Critical examination of interactions between development and the environment and the human dimensions of global change; social, cpolitical, economic, and cultural responses to the management and preservation of natural resources and ecosystems on a global scale. Exploration of the meaning and implications of ?Stewardship of the Earth? and ?Sustainable Development.? Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS450. POLITICAL RISK ASSESSMENT. 3.0 Semester Hrs.
Equivalent with LAIS450,
This course will review the existing methodologies and techniques of risk assessment in both country-specific and global environments. It will also seek to design better ways of assessing and evaluating risk factors for business and public diplomacy in the increasingly globalized context of economy and politics wherein the role of the state is being challenged and redefined. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS460. GEOPOLITICS OF NATURAL RESOURCES. 3.0 Semester Hrs.
Equivalent with LAIS460,
(WI) This seminar examines geopolitical competition between great and aspiring powers for influence, control over land and natural resources, critical geo-strategic trade routes, or even infrastructure. Using empirical evidence from case studies, students develop a deeper understanding of the interconnections between the political, economic, social, cultural and geographic dimensions of foreign policies, as well as issues of war and peace. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.
Course Learning Outcomes

- NA

HASS463. HISTORY OF EPIDEMICS. 3.0 Semester Hrs.
This course explores how epidemics and pandemics have shaped human history, from the Plague of Athens in 430 BCE to the HIV/AIDS crisis. Prerequisite: HASS200.
Course Learning Outcomes

- 1. Understand how epidemics have impacted political, social, and cultural history 2. Explain how human actions determine the course of epidemics 3. Explain how structural inequalities contribute to the spread of epidemics 4. Analyze primary sources and use them to construct historical arguments 5. Craft and deliver strong oral presentations 6. Conduct original historical research using primary source databases and secondary sources and write papers based upon this research.

HASS464. HISTORY OF ENERGY AND THE ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with LAIS464,
This course examines the major patterns of human energy use and interaction with the natural environment on a global scale from the origins of civilization to the present day. Topics analyzed include the dynamics of historical change in energy and resource use, the ways in which energy and the environment have shaped the development of past societies, cultural perceptions of energy and the environment during different historical eras, and the impact of past human activities on natural systems. Analysis of historical trends will also serve as a basis for discussions related to current issues in energy and the environment. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS465. THE GOOD LIFE, FROM ARISTOTLE TO THE ANTHROPOCENE. 3.0 Semester Hrs.
What makes a life meaningful or good? This is an interdisciplinary course that draws upon philosophy, history, and modern behavioral science, to explore how people have historically answered the question of what it means to live a good life. You will read works by thinkers from the ancient world to modernity in conversation with articles and lectures from psychologists and cognitive scientists, and write a research paper that presents your own answer to this question while critically engaging with different philosophical and historical traditions. Other assignments include a short analytical paper, journaling, four experiments conducted over two weeks each to test some of the theories of happiness we will explore, and an oral presentation on the findings of your research project. Prerequisite: HASS100, HASS200.
Course Learning Outcomes

- • Understand, compare, and describe major historical and contemporary theories on how to life a good life, proposed by authors from a variety of cultural backgrounds
- • Write sophisticated essays that combine personal narrative and argument with research and analysis
- • Communicate complex concepts and ideas, orally and in writing, to a variety of audiences
- • Use philosophy and history to examine big questions of enduring concern: What are my requirements for a good life? What things matter the most to me? How can I be happier? How can my life be more meaningful?

HASS466. SCIENCE, TECHNOLOGY, AND CONFUCIAN ETHICS. 3.0 Semester Hrs.
This course examines the ethical ideas in classical Confucianism (e.g., Confucius, Mencius) and how these ethical ideas can shape the ways in which scientific and technological problems are defined and solved. Students in this class will be expected to read both classical Confucian texts such as Analects and Mencius and works by contemporary authors that examine the social, ethical, and political issues in scientific and technological domains such as gene editing technology, robotics, social media technology, and engineering through the lens of Confucian ethics. A major goal of this course is to help students challenge some prevalent ideologies in Western ethics such as autonomous individualism (e.g., individuals are understood as merely rights-bearing persons). It also helps students cultivate a cultural sensitivity toward scientific and technological practice in a global context. Our exploration in this class will help students develop their ?self-knowledge? that has been extensively missing in current engineering education system. Students are encouraged to think reflectively and critically about why they are engineers, for those benefit they want to work, and the kind of world they want to design and live in by using the powerful technologies they create. Prerequisite: HASS200.
Course Learning Outcomes

- understand key ideas and arguments in Confucian ethics
- be able to interpret classical Confucian ethical ideas from the perspectives of contemporary social sciences including anthropology, psychology, and political theory
- be able to compare Confucian ethics with other major schools of thought in Western ethics (e.g., deontology, utilitarianism, social contract theory)
- be able to use theories and tools from Confucian ethics to critique contemporary global, social, and political controversies and scientific and technological advancements

- develop a culturally diverse attitude toward human experience, society, and technological change

HASS467. HISTORY OF EARTH AND ENVIRONMENTAL SCIENCES. 3.0 Semester Hrs.
Equivalent with LAIS467,
This course provides an overview of the history of some of the key sciences that help us understand the world we inhabit: geology, climatology, evolutionary biology, and ecology. As we investigate key scientific discoveries of the modern era, we will also consider the philosophical and cultural impacts of those scientific discoveries. Thus, our reading will include not only original texts by scientists, but also key literary, historical and other texts inspired by those discoveries. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS468. ENVIRONMENTAL JUSTICE. 3.0 Semester Hrs.
This course explores the history of the environmental justice movement, current and emerging environmental justice issues, and the application of environmental justice concepts and theories to environmental decision-making. Course content and activities are designed to enrich student understanding of how environmental injustice is produced (locally, regionally, and globally), how environmental justice issues are measured and analyzed, and how environmentally just outcomes can be achieved. Prerequisite: HASS100. Co-requisite: HASS200.
Course Learning Outcomes

- At the completion of this course, students will be able to: 1) Critically analyze environmental problems, policies, and practices with attention to how and why diverse people/groups are differentially exposed to environmental benefits and burdens. 2) Explain how the concept of environmental justice and social movements oriented around environmental justice have evolved over time. 3) Apply and evaluate concepts, theories, and methods that are central to analyses of environmental justice. 4) Reflect critically your own life and how you shape, and are shaped by, dynamics of environmental justice. 5) Develop an evidence-based and well-reasoned case for what a just outcome of an environmental situation would be. 6) Explore strategies for addressing environmental justice based in different theories of change (e.g., political, economic, ethical, technical). 7) Apply research, writing, oral presentation, and discussion facilitation skills to environmental policy and planning issues.

HASS469. SCIENCE AND SPIRITUALITY. 3.0 Semester Hrs.
The education at Mines focuses on the development and application of science and engineering but leaves little space for the big spiritual questions that arise in most of us. In this 3-credit class, we explore the interface of science and spirituality, and we will study questions such as the following. How did how our worldview change in history? Is the universe a mindless machine? What does quantum mechanics teach us about this? What is the connection between mind and matter? (Does mind matter? Does matter mind?) Why can humans be devils or saints? What are the roles of rational thinking and intuition? This eclectic class is a true exploration in the sense that most questions above cannot be tackled as a science or engineering problem; instead, we will dive in deep together. This is a writing-intensive class that can be used as a 400-level HASS elective.
Course Learning Outcomes

- 1. Describe at least 5 spiritual practices and, after trying at least 3 of these practices each for at least a week, reflect on the impacts of these practices on the development of the self. 2. Identify and describe at least three different views on the degree to which science explains reality, and the need for (or absence of) a spiritual world view. 3. Create a personal worldview statement on science and spirituality. 4. Conduct a respectful conversation on a controversial topic in scientific practice in a spirit of dialogue, and be able to describe best practices for such conversations. 5. Display a willingness to be vulnerable through sharing of personal experiences and by engaging in class activities of a different nature from regular Mines classes. 6. Demonstrate the ability for non-dualistic thinking —i.e., rise above right/wrong or true/false—in the connection of science, spirituality, and religion; share this non-dualistic thinking through papers and class conversations.

HASS483. INTELLECTUAL PROPERTY FOR ENGINEERS AND ARTISTS. 3.0 Semester Hrs.
This course meets weekly, in three-hour blocks. Students will learn about the philosophical and legal concepts that form the foundation for the protection of their unique ideas and expressions. We trace the history of intellectual property, learn how to spot and secure protected intellectual property rights, use practical tools to obtain legal rights by student inventions and expressions, and develop basic business models. Students are expected to come to class prepared, and to engage in discussions and workgroups.
Course Learning Outcomes

- a. Identify specific types on intellectual property (e.g. types of patent, trademark, copyright and trade secrets); b. Articulate the different business and legal implications of property right designations; c. Create actionable business strategies to secure intellectual property rights; d. Appreciate and understand how to implement the practical, ethical aspects of respecting intellectual property rights of others; e. Understand how to respect, and avoid conflicts with other owners of intellectual property rights; f. Develop business plan components to utilize intellectual property in business; g. Understand basic documents for aspects of intellectual property protection (e.g. non-disclosure agreement).

HASS484. US WATER POLITICS AND POLICY. 3.0 Semester Hrs.
(WI) This interdisciplinary seminar course engages the complexities of contemporary water governance in the United States, with an emphasis on the arid American West, including the state of Colorado. It engages with governance questions such as how we are to share over-allocated water resources, how we are to engage with increasingly unpredictable hydrologic dynamics, and how changes in water science, engineering, and values shape policy and politics and vice versa. The course engages with concepts in ethics, economics, history, law, and policy, and puts them in conversation with dynamics in hydrology, engineering, and social-ecological systems theory. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- After successful completion of this course, students will be able to… 1. Demonstrate an understanding of contemporary water politics and policy in the arid American West as compared to the rest of the United States. 2. Thoughtfully and effectively participate in critical discussions of the challenges – past, present, and future – facing United States water stakeholders and decision-makers. 3. Articulate an individual water ethic and reflect upon its connections to broader governance structures and processes. 4. Practice interdisciplinary analysis by conducting a watershed assessment that integrates social with hydrologic/ecologic dynamics and articulates grounded policy. recommendations. 5. Synthesize ideas from diverse sources and communicate them clearly and compellingly in a variety of career- and policy-relevant formats.

HASS485. CONSTITUTIONAL LAW AND POLITICS. 3.0 Semester Hrs.
Equivalent with LAIS485,
This course presents a comprehensive survey of the U.S. Constitution with special attention devoted to the first ten Amendments, also known as the Bill of Rights. Since the Constitution is primarily a legal document, the class will adopt a legal approach to constitutional interpretation. However, as the historical and political context of constitutional interpretation is inseparable from the legal analysis, these areas will also be covered. Significant current developments in constitutional jurisprudence will also be examined. The first part of the course deals with Articles I through III of the Constitution, which specify the division of national governmental power among the executive, legislative, and judicial branches of government. Additionally, the federal nature of the American governmental system, in which governmental authority is apportioned between the national government and the state governments, will be studied. The second part of the course examines the individual rights specifically protected by the amendments to the Constitution, principally the First, Fourth, Fifth, Sixth, Eighth, and Fourteenth Amendments. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS486. SCIENCE AND TECHNOLOGY POLICY. 3.0 Semester Hrs.
Equivalent with LAIS486,
An examination of current issues relating to science and technology policy in the United States and, as appropriate, in other countries. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS487. ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS487,
Seminar on environmental policies and the political and governmental processes that produce them. Group discussion and independent research on specific environmental issues. Primary but not exclusive focus on the U.S. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS488. GLOBAL WATER POLITICS AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS488,
(WI) This interdisciplinary seminar course analyzes how droughts, floods, water management, global trading system, and climate change affect the hydrological and food systems that are critically important for economic prosperity and political stability. It addresses water policy at scales that range from community level to global governance regimes. It uses relevant analytical perspectives of, for example, psychology, political economy, development studies, and institutional approaches in economic geography to help students understand how certain transboundary water conflicts have emerged, their national and regional implications, and policies and institutions that can be used to resolve them. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.
Course Learning Outcomes

- At the conclusion of the class students will understand: • Key issues in water politics and policy in the Middle East • The various types of threats to water infrastructure • The political economy of the water-food-energy nexus • Costs and benefits of farming abroad versus food imports • How domestic and international politics can affect water conflict and food security • How water policy and management are shaped and re-shaped by different forces and stakeholders • Issues pertaining to international watercourses and their effect on economic development and regional security • Literature in international water resources planning and development.

HASS490. ENERGY AND SOCIETY. 3.0 Semester Hrs.
Equivalent with ENGY490,LAIS490,MNGN490,
An interdisciplinary capstone seminar that explores a spectrum of approaches to the understanding, planning, and implementation of energy production and use, including those typical of diverse private and public (national and international) corporations, organizations, states, and agencies. Aspects of global energy policy that may be considered include the historical, social, cultural, economic, ethical, political, and environmental aspects of energy together with comparative methodologies and assessments of diverse forms of energy development as these affect particular communities and societies. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS491. ENERGY POLITICS. 3.0 Semester Hrs.
(WI) We will use political science approaches, theories, and methods to investigate the global, regional, state, and local politics of renewable and non-renewable energy, spanning all uses: transportation, heating and cooling, and electricity. We will look at the politics behind energy in a subset of countries to be chosen by the class, such as China, Brazil, India, Austria, Spain, Venezuela, and Germany. We will then focus on energy in Colorado and other US states, conducting primary research on the stakeholders and the relevant political outcomes. We will hear from energy companies, non-governmental organizations, university and research entities, government representatives, legislators, and local activists. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- understand issues surrounding the politics of a variety of energy sources
- create and execute a sophisticated research design focused on political issues related to energy, including writing a literature review and being able to identify and operationalize independent and dependent variables and create causal mechanisms
- use basic social science research methods, such as surveys and interviews
- develop written and oral communication skills

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498B,
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498C,
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498D,

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498E,
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498F,
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498G,
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498H,
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HNRS105. INNOVATION AND DISCOVERY IN ENGINEERING, ARTS, AND SCIENCES I. 3.0 Semester Hrs.
(I) (WI) "Innovation and Discovery in Engineering, Arts, and Sciences" (IDEAS) applies honors pedagogies in a multidisciplinary, integrated environment that highlights the seamless boundaries between science and engineering, design, ethics, and the arts as a path toward making value-informed technical decisions. In addition to developing foundational skills in engineering design and problem-solving, students examine place, identity, citizenship, and community in various contexts as they learn what it means to be an engaged and mindful citizen and professional. IDEAS poses ethical problems and hands-on design challenges from a multitude of lenses. It incorporates experiential learning, team-based projects, and seminar discussions to encourage students to think both critically and creatively about their world. Students must pass both HNRS105 and HNRS 115 to meet degree requirements. If students drop either of these courses, they must take both HASS100 and EDNS151 or their equivalents in order to graduate.
Course Learning Outcomes

- Identify design problems that respond to needs of place, identity, citizen, and community.
- Recognize and utilize multiple perspectives in the problem-definition process.
- Analyze self and community through multidisciplinary techniques.
- Evaluate a place using ethical, environmental, societal, and cultural lenses.
- Utilize observational and ethnographic research methods.
- Engage in design charrettes, writing projects, and rapid prototyping activities that demonstrate user empathy, values-sensitive design, creativity, synthesis, and/or reflection.
- Give and receive feedback during peer review and portfolio development.
- Increase ethical sensitivity and add to ethical judgment.
- Visually communicate ideas through hand sketching.
- Use written, oral, and graphic communication as a means to discover and reconsider ideas through a process of drafting, collaborating, revising, and editing.

HNRS110. LEADERSHIP BY DESIGN I. 3.0 Semester Hrs.
In the first of two semesters of this honors experience, students participate in a multidisciplinary, integrated, collaborative environment that blends leadership, design, communication, innovation, and ethics in order to build the capabilities needed to lead and address grand challenges. Students will experience a combination of experiential learning, projects, seminar discussions, guest speakers, and design sprints as they spend time gaining foundational knowledge, learning how to think in systems, analyzing grand challenges, communicating ?the story? in multiple ways to various audiences, and designing documents, presentations, objects, and exhibitions. Also, students will begin to develop their portfolio to document the story of their time in Leadership by Design. Students must pass both HNRS110 and HNRS120 to meet degree requirements.
Course Learning Outcomes

- Develop your Capabilities and Mindsets through these 10 C's, so that you Grow as a leader, communicator, thinker, designer, maker, innovator, and collaborator

HNRS115. INNOVATION AND DISCOVERY IN ENGINEERING, ARTS, AND SCIENCES II. 4.0 Semester Hrs.
(WI) "Innovation and Discovery in Engineering, Arts, and Sciences" (IDEAS) applies honors pedagogies in a multidisciplinary, integrated environment that highlights the seamless boundaries between science and engineering, design, ethics, and the arts as a path toward making value-informed technical decisions. Students examine place, identity, citizenship, and community in various contexts as they learn what it means to be an engaged and mindful citizen and professional. IDEAS poses ethical problems and hands-on design challenges from a multitude of lenses. It incorporates experiential learning, team-based projects, and seminar discussions to encourage students to think both critically and creatively about their world. Students must pass both HNRS105 and HNRS115 to meet degree requirements. If students drop either of these courses, they must take both HASS100 and EDNS151 or their equivalents in order to graduate. Prerequisite: HNRS105 with a grade of C- or higher.
Course Learning Outcomes

- Model and communicate formalized design ideas through the use of standardized engineering graphics conventions and computer-aided design/solid modeling software.
- Apply the professional techniques of leadership and team membership in the context of project management.
- Research and analyze an engineered or natural system through multidisciplinary techniques.

- Analyze and evaluate the needs, values, and perspectives of human and non-human stakeholders.
- Design solutions through an iterative testing, refining, and feedback process based on bibliographic research, analysis of technical requirements, environmental risks, user empathy, and stakeholder engagement.
- Develop written and oral arguments that meet the needs of varying rhetorical situations.
- Recognize the need for engineering solutions that are responsive to a multicultural and globalized world.
- Apply ethical reasoning in support of an engineering design solution.

HNRS120. LEADERSHIP BY DESIGN II. 3.0 Semester Hrs.
In the second of two semesters of this honors experience, students participate in a multidisciplinary, integrated, collaborative environment that blends leadership, design, communication, innovation, and ethics in order to build the capabilities needed to lead and address grand challenges. Students will experience a combination of experiential learning, projects, seminar discussions, professional development workshops, guest speakers, and design sprints. Students build on the first semester as they build leadership skills and work to be better designers, creators, thinkers, innovators, and communicators. They will address the questions ?What is good design?? ?What is good leadership?? ?What is innovation?? and ?How do I best tell the story?? Students design documents, presentations, and objects. They investigate ways to create impact and value as they define problems, pose solutions for grand challenges, and create a portfolio to document their experience to best tell the story of their time in Leadership by Design. Students must pass both HNRS110 and HNRS120 to meet degree requirements. Prerequisite: HNRS110 with a grade of C- or better.
Course Learning Outcomes

- Develop your Capabilities and Mindsets through these 10 C's, so that you Grow as a leader, communicator, thinker, designer, maker, innovator, and collaborator

HNRS150. ENTERING RESEARCH. 1.0 Semester Hr.
In this course, students will be introduced to various skills needed to be successful when conducting research. These skills include best practices to finding a research mentor, the roles and responsibilities of a researcher, developing relationships that make for a successful research experience, how to critically read and analyze scientific literature, lab safety, and disseminating research work.
Course Learning Outcomes

- Student Learning Outcomes

HNRS198. SPECIAL TOPICS. 6.0 Semester Hrs.
A Special Topics course will be a pilot course in the UHSP curriculum or will be offered as an enhancement to regularly-scheduled UHSP seminars. Special Topics courses in the UHSP curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS199. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a UHSP student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled UHSP curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS298. SPECIAL TOPICS. 1-6 Semester Hr.
A Special Topics course will be a pilot course in the UHSP curriculum or will be offered as an enhancement to regularly-scheduled UHSP seminars. Special Topics courses in the UHSP curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS299. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a UHSP student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled UHSP curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS305. EXPLORATIONS IN MODERN AMERICA. 3.0 Semester Hrs.
(WI) Honors core course that develops student skills in reading, writing, critical thinking, and oral communication. skills through the exploration of selected topics related to the social, cultural, and political ideas and events that have shaped the development of the modern United States and its role in the world. 3 lecture hours, 3 credit hours. Prerequisite: HASS100 or HNRS105, HNRS115 or HNRS110, HNRS120 or HNRS198A.

HNRS315. EXPLORATIONS IN THE MODERN WORLD. 3.0 Semester Hrs.
(WI) Honors core course that develops student writing skills and critical thinking abilities through the exploration of selected topics related to the social, cultural, and political ideas and developments that have shaped the modern world. 3 lecture hours, 3 credit hours. Prerequisite: HASS100 or HNRS105, HNRS115 or HNRS110, HNRS120 or HNRS198A.

HNRS398. SPECIAL TOPICS IN THE UNIVERSITY HONORS AND SCHOLARS PROGRAM. 1-6 Semester Hr.
A Special Topics course will be a pilot course in the University Honors & Scholars Programs curriculum or will be offered as an enhancement to regularly-scheduled UHSP seminars. Special Topics courses in the UHSP curriculum will not be offered more than twice.

HNRS399. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a UHSP student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled UHSP curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS405. MCBRIDE PRACTICUM. 1-3 Semester Hr.
(I, II) (WI) With approval of the Program, a McBride student may enroll in an individualized study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. This option may be used to pursue an approved foreign study program, service learning program, international internship, undergraduate research project, or other authorized experiential learning program of study. Students must also prepare a faculty-guided major research paper that integrates the experience with the goals, objectives, and focus of the Honors Program in Public Affairs. 1-3 semester hours. Repeatable up to 6 hours.

HNRS425. EXPLORATIONS IN POLITICS, POLICY, AND LEADERSHIP. 3.0 Semester Hrs.
(WI) Study of selected topics related to policy, politics, and/or leadership through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in The Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS430. EXPLORATIONS IN IDEAS, ETHICS, AND RELIGION. 3.0 Semester Hrs.
(WI) Study of selected topics related to ideas, ethics, and/or religion through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS435. EXPLORATIONS IN CULTURE, SOCIETY, AND CREATIVE ARTS. 3.0 Semester Hrs.
(WI) Study of selected topics related to culture, society, and/or the creative arts through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS440. EXPLORATIONS IN INTERNATIONAL STUDIES & GLOBAL AFFAIRS. 3.0 Semester Hrs.
(WI) Study of selected topics related to international studies and/or global affairs through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS445. EXPLORATIONS IN SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.
(WI) Study of selected topics related to the relationships between science, technology, and society through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS450. EXPLORATIONS IN EARTH, ENERGY, AND ENVIRONMENT. 3.0 Semester Hrs.
(WI) Study of selected topics related to earth, energy, and/or the environment through case studies, readings, research, and writing. This course may focus on the human dimensions or broader impacts of science, technology, engineering, or mathematics. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS476. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.
(II) Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student?s learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. Prerequisites: none. 2 hours lecture; 3-4 hours lab; 3.0 semester hours.

HNRS496. PAYNE SCHOLARS PROGRAM. 1.0 Semester Hr.
Mines graduates often go on to become corporate leaders and are responsible for many of the innovations and changes seen across industries. In much the same way, the research done at Mines has far reaching implications for many of the social, economic, and environmental challenges faced around the world. To develop these relationships, and to prepare students for future roles, the Payne Institute partnered with students to develop a public policy community that uses all the School of Mines? resources to be both physical and social engineers of the world around them. One of the most prominent ways we do this is through the Payne Scholars program. This one-credit course helps students perform research, collaborate across campus, and engage with a broad network of international experts on global policy challenges. Students are taught how to write academic papers on the important issues we are facing today, and once the students finish the course, the papers they write can be published as Payne Commentaries on our website. We often sponsor students for internships, or offer student worker positions to continue their work. This often means that they get to be co-authors on peer-reviewed academic papers or help us build world-shaping policy.

HNRS498. SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS. 1-6 Semester Hr.
A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS499. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

LICM198. SPECIAL TOPICS. 0.5-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LICM298. SPECIAL TOPICS. 0.5-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL113. SPANISH I. 3.0 Semester Hrs.
Fundamentals of spoken and written Spanish with an emphasis on vocabulary, idiomatic expressions of daily conversation, and Spanish American culture. 3 semester hours.

LIFL114. ARABIC I. 3.0 Semester Hrs.
Fundamentals of spoken and written Arabic with an emphasis on vocabulary, idiomatic expressions of daily conversation, and culture of Arabic-speaking societies. 3 semester hours.

LIFL115. GERMAN I. 3.0 Semester Hrs.
Fundamentals of spoken and written German with an emphasis on vocabulary, idiomatic expressions of daily conversation, and German culture. 3 semester hours.

LIFL119. FRENCH I. 3.0 Semester Hrs.
(I) French I provides basic instruction in speaking, reading, listening, and writing the French language, with emphasis in class on communicating through speaking and listening skills. French and francophone culture will also be studied. Successful completion of French I will allow students to further their french studies in level 2. 3 hours lecture, 3 semester hours.

LIFL123. SPANISH II. 3.0 Semester Hrs.
Continuation of Spanish I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL124. ARABIC II. 3.0 Semester Hrs.
Continuation of Arabic I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and culture of Arabic speaking societies. 3 semester hours.

LIFL125. GERMAN II. 3.0 Semester Hrs.
Continuation of German I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and German culture. 3 semester hours.

LIFL129. FRENCH II. 3.0 Semester Hrs.
French 2 provides continued instruction in speaking, reading, listening, and writing the French language, with emphasis in class on communicating through speaking and listening skills. French and francophone culture will also be studied. 3 hours lecture. Prerequisite: LIFL119.

LIFL198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL213. SPANISH III. 3.0 Semester Hrs.
Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL299. INDEPENDENT STUDY. 6.0 Semester Hrs.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU101. CSM CONCERT/MARCH BAND-FRESHMAN. 1.0 Semester Hr.
Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU102. COLORADO SCHOOL OF MINES SYMPHONY ORCHESTRA - FRESHMAN. 1.0 Semester Hr.
(I, II, S) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. Offered every other year. 3 hours lab; 1 semester hour.
Course Learning Outcomes

- Generally, students will study two large symphonic works and four less complex pieces per semester in addition to one to three small chamber works of varying complexity.

LIMU111. CSM CONCERT CHOIR - FRESHMAN. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU112. CSM CONCERT CHOIR - FRESHMAN. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU121. GUITAR ENSEMBLE. 1.0 Semester Hr.
(I, II, S) Students will learn the basics of classical guitar playing in a non-threatening environment. Utilizing beginning to intermediate classical guitar tunes, students will advance the fundamental guitar technique as well as the music reading skill on classical guitar. Reading skill is the foundation of students? future engagement with all forms of music, therefore considerable amount of class resources will be devoted to this particular discipline. Participation in the departmental concert at the end of the semester is mandatory. Offered every other year. 3 hours lab; 1 semester hour.
Course Learning Outcomes

- o Learn and understand the fundamental classical guitar technique o Learn to play classical guitar ensemble pieces from various time periods o Being able to follow the conductor and play in time o The ability to read standard music notation on the guitar will be stressed throughout the semester

LIMU189. INDIVIDUAL INSTRUMENTAL OR VOCAL MUSIC INSTRUCTION. 1.0 Semester Hr.
(I, II) The course affords the student an opportunity to study privately with CSM music faculty on a wide range of instruments including guitar, piano, bass guitar, voice, saxophone, flute, drums and world instruments. Students will be required to practice regularly and demonstrate

proficiency on their instrument/voice. Topics of this class will include performance etiquette, musicianship, musical styles, stylistic vocabulary, foreign language and basic music theory. 1 credit hour.

LIMU198. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU201. CSM CONCERT/MARCH BAND-SOPHOMORE. 1.0 Semester Hr.
Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU202. COLORADO SCHOOL OF MINES SYMPHONY ORCHESTRA - SOPHOMORE. 1.0 Semester Hr.
(II) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. Offered every other year. 3 hours lab; 1 semester hour.
Course Learning Outcomes

- While performance repertoire changes a great deal due to the nature of ensemble music education, technical studies will remain consistent. Technical studies are meant to improve physical ability on students' instruments and include scales and arpeggios as well as intonation interval drills. Bach chorales are used to study balance, blend, and intonation in a simplified setting.

LIMU211. csm CONCERT CHOIR - SOPHOMORE. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU212. CSM CONCERT CHOIR - SOPHOMORE. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU301. CSM CONCERT/MARCH BAND-JUNIOR. 1.0 Semester Hr.
Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU302. COLORADO SCHOOL OF MINES SYMPHONY ORCHESTRA - JUNIOR. 1.0 Semester Hr.
(II) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. Offered every other year. 3 hours lab; 1 semester hour.
Course Learning Outcomes

- The Colorado School of Mines Symphony Orchestra seeks to develop musicianship, communication, leadership, and social engagement through the study of standard orchestral repertoire, current popular repertoire, film soundtracks, and chamber music. Further, orchestral music education helps students develop critical listening and problem-solving skills, independently seek out new information, explore how historical and theoretical context informs interpretation, and to stimulate their desire to strive for excellence.

LIMU311. CSM CONCERT CHOIR - JUNIOR. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU312. CSM CONCERT CHOIR - JUNIOR. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU401. CSM CONCERT/MARCH BAND-SENIOR. 1.0 Semester Hr.
(I) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. 3 hours lab; 1 semester hour.
Course Learning Outcomes

- While performance repertoire changes a great deal due to the nature of ensemble music education, technical studies will remain consistent. Technical studies are meant to improve physical ability on students' instruments and include scales and arpeggios as well as intonation interval drills. Bach chorales are used to study balance, blend, and intonation in a simplified setting.

LIMU402. COLORADO SCHOOL OF MINES SYMPHONY ORCHESTRA - SENIOR. 1.0 Semester Hr.
(II) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. Offered every other year. 3 hours lab; 1 semester hour.
Course Learning Outcomes

- Technical studies are meant to improve physical ability on students' instruments and include scales and arpeggios as well as intonation interval drills. Bach chorales are used to study balance, blend, and intonation in a simplified setting.

LIMU411. CSM CONCERT CHOIR - SENIOR. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU412. CSM CONCERT CHOIR - SENIOR. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU421. JAZZ ENSEMBLE. 1.0 Semester Hr.
FALL The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance (s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU422. JAZZ ENSEMBLE - SPRING. 1.0 Semester Hr.
SPRING The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU423. JAZZ LAB. 1.0 Semester Hr.
The Jazz Lab provides an opportunity for students to participate in a musical ensemble in the jazz combo format. Jazz music is a unique American art form. The jazz combo format is an exciting way for students to experience the joy and sense of achievement of performing this great American music form. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU450. MUSIC TECHNOLOGY CAPSTONE COURSE. 3.0 Semester Hrs.
Project-based course designed to develop practical technological and communication skills for direct application to the music recording. Prerequisite: LIMU340 and LIMU350. 3 hours seminar; 3 semester hours.

LIMU498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Professors

Hussein A. Amery

Lucas Bessire, effective January 2025

Jon Leydens

Kenneth Osgood

Associate Professors

Tina L. Gianquitto

Kathleen J. Hancock

Adrianne Kroepsch

James D. Straker

Teaching Professors

Cortney Holles

Jonathan Cullison

Paula A. Farca

Joseph Horan

Derrick Hudson, NREP Graduate Program Director

Shannon Davies Mancus, Associate Department Head

Seth Tucker

Sandy Woodson, Department Head

Teaching Associate Professors

Eliza Buhrer

Heather Fester

Teaching Assistant Professors

Mairead Case

Masakasu Ito

Alison Kerr

Brianna Wolfe

Hennebach Visiting Assistant Professor

Angeline Letourneau

Professors Emeriti

W. John Cieslewicz

T. Graham Hereford

Carl Mitcham

Barbara M. Olds

Eul-Soo Pang

Anton G. Pegis

Thomas Philipose, University professor emeriti

Arthur B. Sacks

Associate Professors Emeriti

Betty J. Cannon

John Heilbrunn

Kathleen H. Ochs

Laura J. Pang

Karen B. Wiley

Teaching Professor Emeriti

Robert Klimek

James Jesudason

Teaching Associate Professor Emerti

Rose Pass

Mechanical Engineering

Program Description

The Mechanical Engineering Department offers a design-oriented, project-based undergraduate program that emphasizes fundamental engineering principles, with many courses providing hands-on and active learning experiences. Students receive a strong foundation in mechanical engineering disciplines and a working knowledge of modern engineering tools, e.g., design and manufacturing techniques. To explore the many opportunities as a mechanical engineer, students may choose a track which provides depth in specific areas, e.g., automotive, aerospace, biomechanics, energy and manufacturing, among others. With over 80% of our students participating in industry-sponsored internships or research with our faculty, our graduates are well prepared for a mechanical engineering career in a world of rapid technological change.

The Bachelor of Science in Mechanical Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission’s General Criteria and Program Criteria for Mechanical Engineering.

Bachelor of Science in Mechanical Engineering

The Mechanical Engineering program intentionally embeds professional and technical skills, e.g., working on teams, engineering design, technical communication, and programming throughout the Mechanical Engineering curriculum. Our project-based design spine is bookended by the first-year experience in Introduction to Design (EDNS151) and our multidisciplinary capstone experience (EDNS 491 & 492) in the senior year. Following their first year at Mines, our students enter our project-based design spine in the middle years (sophomore and junior years):

- MEGN200 Introduction to ME: Programming & Hardware Interface. This course has students utilizing Arduinos while learning to program and breadboard to respond to an open-ended design problem.
- MEGN201 Introduction to ME: Design & Fabrication. In this course, students learn to design in SolidWorks, create technical drawings, use GD&T, and fabricate components in our machine shop with manual and CNC equipment.
- MEGN 300 Instrumentation and Automation: This course teaches our students to use more advanced instrumentation to collect and interpret real engineering data. Students use the LabVIEW programming language to design and control their devices and experiments.
- MEGN301 Mechanical Integration & Design. In this course students utilize the skills from the previous three courses as well as other ME courses to design, build and test their solution to an open-ended design project. This semester-long project immerses students in the design process and utilizes Scrum process to respond to project milestones.

This project-based experience teaches design methodology and stresses the creative aspects of the mechanical engineering profession. The courses help prepare students for open-ended, industry-based projects in the senior design experience.

Additionally, students complete an advanced mechanical engineering core that includes fluid mechanics, thermodynamics, dynamics, heat transfer, numerical methods, machine design, finite element analysis, and manufacturing processes. This engineering core is complemented by courses and electives in Culture and Society (CAS), which elaborate on the societal and economic impact of engineering solutions in our world. Students also take four advanced technical electives and three additional free electives to explore specific areas of interest. If students want to gain depth in a particular area on mechanical engineering, they can align their four ME electives in one of our eight tracks: Aerospace, Automotive, Automation and Controls, Biomechanics, Energy, Manufacturing, Materials, and Nuclear Energy.

There are plenty of opportunities outside of the curriculum for students to explore their passions. We have active Mines Maker Space, Robotics Club, and Formula SAE student groups among the over 300 student groups on campus, where students engage with the community, arts, and the outdoors.

Program Educational Objectives (Bachelor of Science in Mechanical Engineering)

The Mechanical Engineering program contributes to the educational objectives described in the Mines' Graduate Profile and the ABET accreditation criteria. Accordingly, the Mechanical Engineering program at Mines has established the following program educational objectives for the BS in Mechanical Engineering degree:

The Mechanical Engineering program prepares graduates within three to five years of completing their degree to:

- Apply their Mechanical Engineering education as active contributors to their professional community and society more broadly;
- Effectively communicate information and its practical and societal impact to a diverse and globally integrated society;
- Demonstrate their commitment to professional development and life-long learning through workforce readiness training, professional community involvement, and community outreach;
- Embody ethical, environmental and societal responsibility encompassing diversity, equity and inclusion in their professional activities.

Student Outcomes

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Bachelor of Science in Mechanical Engineering Degree Requirements:

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
EDNS151	CORNERSTONE - DESIGN I			3.0
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
S&W	SUCCESS AND WELLNESS			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
HASS200	GLOBAL STUDIES			3.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				15.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
CEEN241	STATICS			3.0
MTGN202	ENGINEERED MATERIALS			3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
MEGN200	INTRODUCTION TO MECHANICAL ENGINEERING: PROGRAMMING AND HARDWARE INTERFACE or 201			3.0
OR MEGN201	INTRODUCTION TO MECHANICAL ENGINEERING: DESIGN & FABRICATION			
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
				17.0
Spring		**lec**	**lab**	**sem.hrs**
EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
MEGN212	INTRODUCTION TO SOLID MECHANICS			3.0
MEGN261	THERMODYNAMICS I			3.0
MEGN201	INTRODUCTION TO MECHANICAL ENGINEERING: DESIGN & FABRICATION			3.0

		lec	lab	sem.hrs
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
				18.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING			3.0
MEGN300	INSTRUMENTATION & AUTOMATION			3.0
MEGN315	DYNAMICS			3.0
MEGN324	INTRODUCTION TO FINITE ELEMENT ANALYSIS			3.0
CAS	MID-LEVEL CAS			3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
MEGN301	MECHANICAL INTEGRATION & DESIGN			3.0
MEGN351	FLUID MECHANICS			3.0
MEGN381	MANUFACTURING PROCESSES			3.0
MEGN481	MACHINE DESIGN			3.0
MECH ELECT	Mechanical Engineering Elective*			3.0
				15.0

Senior

Fall		**lec**	**lab**	**sem.hrs**
EDNS491	CAPSTONE DESIGN I			3.0
MEGN471	HEAT TRANSFER			3.0
MECH ELECT	Advanced Engineering Sciences Elective*			3.0
MECH ELECT	Mechanical Engineering Elective*			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
EDNS492	CAPSTONE DESIGN II			3.0
MECH ELECT	Mechanical Engineering Elective*			3.0
FREE	Free Elective			3.0
FREE	Free Elective			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
				15.0

Total Semester Hrs: 126.0

* Mechanical Engineering students are required to take three Mechanical Engineering elective courses. At least one of these courses must be from the Advanced Engineering Sciences list. The remaining must be from either the Advanced Engineering Sciences list or the Mechanical Engineering Electives list.

Advanced Engineering Sciences:

MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
MEGN416	ENGINEERING VIBRATION	3.0
MEGN451	AERODYNAMICS	3.0
MEGN461	THERMODYNAMICS II	3.0

Mechanical Engineering Electives:

CEEN401	LIFE CYCLE ASSESSMENT	3.0
CEEN405	NUMERICAL METHODS FOR ENGINEERS	3.0
CEEN406	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN433	MATRIX STRUCTURAL ANALYSIS	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
EDNS401	PROJECTS FOR PEOPLE	3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0
EENG390	ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID	3.0
EENG417	MODERN CONTROL DESIGN	3.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
MEGN391	INTRODUCTION TO AUTOMOTIVE DESIGN	3.0
MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MEGN454	ORBITAL MECHANICS	3.0
MEGN456	SPACE OPERATIONS AND MISSION DESIGN	3.0
MEGN466	INTRODUCTION TO INTERNAL COMBUSTION ENGINES	3.0
MEGN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MEGN485	MANUFACTURING OPTIMIZATION WITH NETWORK MODELS	3.0
MEGN486	LINEAR OPTIMIZATION	3.0
MEGN487	NONLINEAR OPTIMIZATION	3.0
MEGN488	INTEGER OPTIMIZATION	3.0
MEGN498	SPECIAL TOPICS IN MECHANICAL ENGINEERING (SPECIAL TOPICS)	1-6
MEGN5XX	ANY 500-LEVEL MEGN COURSE	3.0
MTGN211	STRUCTURE OF MATERIALS	3.0
MTGN442	ENGINEERING ALLOYS	3.0
MTGN445	MECHANICAL PROPERTIES OF MATERIALS	3.0
MTGN464	FORGING AND FORMING	2.0
MTGN472	BIOMATERIALS I	3.0

MTGN475	METALLURGY OF WELDING	2.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
PHGN350	INTERMEDIATE MECHANICS	4.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0
PHGN466	MODERN OPTICAL ENGINEERING	3.0
AMFG401	ADDITIVE MANUFACTURING	3.0
AMFG421	DESIGN FOR ADDITIVE MANUFACTURING	3.0
or AMFG521	DESIGN FOR ADDITIVE MANUFACTURING	
AMFG422	LEAN MANUFACTURING	3.0
AMFG4XX	Not Including 499	3.0
AMFG531	MATERIALS FOR ADDITIVE MANUFACTURING	3.0
AMFG511	DATA DRIVEN ADVANCED MANUFACTURING	3.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN	3.0
CSCI306	SOFTWARE ENGINEERING	3.0
CSCI341	COMPUTER ORGANIZATION	3.0
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI437	INTRODUCTION TO COMPUTER VISION	3.0
CSCI442	OPERATING SYSTEMS	3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING	3.0
CSCI473	ROBOT PROGRAMMING AND PERCEPTION	3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG310	INFORMATION SYSTEMS SCIENCE I	3.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0
EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS	3.0
EENG421	SEMICONDUCTOR DEVICE PHYSICS AND DESIGN	3.0
MATH324	STATISTICAL MODELING	3.0
MATH332	LINEAR ALGEBRA	3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH432	SPATIAL STATISTICS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MEGN4XX	Mechanical Tech Elective (not including 499 & required 400-level courses)	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
CSCI5XX	Non-project and research credit	
EENG5XX	Non-seminar and research credit	
FEGN5XX	Non-project and research credit	
MATH5XX	Non-project and research credit	
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CEEN570	WATER AND WASTEWATER TREATMENT	3.0
EBGN553	PROJECT MANAGEMENT	3.0
MNGN444	EXPLOSIVES ENGINEERING II	3.0
MTGN333	INTRODUCTION TO BLADESMITHING	3.0
INNO444	INNOV8X CREATE	3.0
INNO544	INNOV8X CREATE DSCI	1.0

Major GPA

During the 2016-2017 Academic Year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- CEEN241
- EDNS491
- EDNS492
- MEGN100 through MEGN699 inclusive

Tracks for me undergraduate program

Tracks in Mechanical Engineering offer an opportunity for ME undergrads to explore various topics in mechanical engineering in more depth. Students gain depth in the areas by focusing their ME Electives on four courses prescribed in each track. Each proposed track is defined below with one course required in the Advanced Engineering Science Elective and three courses required from the ME Elective courses. Note that undergraduate students are not required to align with a track. Tracks are suggestions for students to gain advanced knowledge in a subdiscipline area and are "transcriptable."

Aerospace

Advanced Engineering Science Elective		
MEGN451	AERODYNAMICS	3.0
ME Elective (select 3 courses)		
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MEGN452	INTRO TO SPACE EXPLORATION AND RESOURCES	3.0
MEGN453	AEROSPACE STRUCTURES	3.0
MEGN454	ORBITAL MECHANICS	3.0
MEGN455	AEROSPACE SYSTEMS ENGINEERING	3.0
MEGN456	SPACE OPERATIONS AND MISSION DESIGN	3.0

Automation & Controls

Advanced Engineering Science Elective		
MEGN416	ENGINEERING VIBRATION	3.0
ME Elective (select 3 courses)		
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG383	EMBEDDED SYSTEMS	4.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0
EENG411	DIGITAL SIGNAL PROCESSING	3.0
EENG417	MODERN CONTROL DESIGN	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MEGN452	INTRO TO SPACE EXPLORATION AND RESOURCES	3.0

MEGN485	MANUFACTURING OPTIMIZATION WITH NETWORK MODELS	3.0
MEGN540	MECHATRONICS	3.0

Automotive

Advanced Engineering Science Elective (select 1 course)		
MEGN451	AERODYNAMICS	3.0
MEGN461	THERMODYNAMICS II	3.0
Must take both:		
MEGN391	INTRODUCTION TO AUTOMOTIVE DESIGN	3.0
MEGN417	VEHICLE DYNAMICS & POWERTRAIN SYSTEMS	3.0
ME Elective (select 1 course)		
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
MEGN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MEGN466	INTRODUCTION TO INTERNAL COMBUSTION ENGINES	3.0
MEGN465	ELECTRIC VEHICLE POWERTRAIN SYSTEMS	3.0

Biomechanics

Advanced Engineering Science Elective		
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
or MEGN416	ENGINEERING VIBRATION	
ME Elective (select 3 courses)		
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MEGN536	COMPUTATIONAL BIOMECHANICS	3.0
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING	3.0
MTGN472	BIOMATERIALS I	3.0
FEGN525	ADVANCED FEA THEORY & PRACTICE	3.0

Energy

Advanced Engineering Science Elective		
MEGN461	THERMODYNAMICS II	3.0
ME Elective (select 3 courses)		
Choose 1 of the following:		
MEGN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MEGN466	INTRODUCTION TO INTERNAL COMBUSTION ENGINES	3.0
MEGN467	PRINCIPLES OF BUILDING SCIENCE	3.0
Choose 2 of the following courses or from above:		
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0
EENG390	ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID	3.0
MEGN560	DESIGN AND SIMULATION OF THERMAL SYSTEMS	3.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0

Manufacturing

Advanced Engineering Science Elective		
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
ME Elective (select 3 courses)		
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MTGN464	FORGING AND FORMING	2.0
AMFG401	ADDITIVE MANUFACTURING	3.0
AMFG422	LEAN MANUFACTURING	3.0

Materials

Advanced Engineering Science Elective		
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
ME Elective (select 3 courses)		
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MEGN511	FATIGUE AND FRACTURE	3.0
MTGN211	STRUCTURE OF MATERIALS	3.0
MTGN445	MECHANICAL PROPERTIES OF MATERIALS	3.0
MTGN464	FORGING AND FORMING	2.0
MTGN475	METALLURGY OF WELDING	2.0

Nuclear Energy

Advanced Engineering Science Elective		
MEGN461	THERMODYNAMICS II	3.0
ME Elective (select 3 courses)		
ENGY475	INTRODUCTION TO NUCLEAR ENGINEERING	3.0
NUGN506	NUCLEAR FUEL CYCLE	3.0
NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
MEGN487	NONLINEAR OPTIMIZATION	3.0
MEGN488	INTEGER OPTIMIZATION	3.0
MEGN592	RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN	3.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
MTGN598	NUCLEAR MATERIALS POLITICS AND POLICY	3.0
NUGN598	MACHINE LEARNING IN NUCLEAR	3.0
SPRS598A	SPACE NUCLEAR POWER SYSTEMS	3.0

Combined Mechanical Engineering Baccalaureate and Masters Degrees

Mechanical Engineering offers a five year combined program in which students have the opportunity to obtain specific engineering skills supplemented with graduate coursework in mechanical engineering. Upon completion of the program, students receive two degrees, the Bachelor of Science in Mechanical Engineering and the Master of Science in Mechanical Engineering.

Admission into a graduate degree program as a Combined Undergraduate/Graduate degree student may occur as early as the first semester Junior year and *must be granted no later than the end of* *registration the last semester Senior year*. Students must meet minimum GPA admission requirements for the graduate degree.

Students enrolled in Mines' combined undergraduate/graduate program may double count up to six credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with "B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

The Mechanical Engineering Graduate Bulletin provides detail into the graduate program and includes specific instructions regarding required and elective courses. Students may switch from the combined program, which includes a non-thesis Master of Science degree to a M.S. degree with a thesis option; however, if students change degree programs they must satisfy all degree requirements for the M.S. with thesis degree.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Mechanical Engineering Areas of Special Interest (ASI) and Minor Programs

General Requirements

The Mechanical Engineering department offers minor and ASI programs. Students who elect an ASI or minor, must fulfill all prerequisite requirements for each course in a chosen sequence. Students in the sciences or mathematics must be prepared to meet prerequisite requirements in fundamental engineering and engineering science courses. Students in engineering disciplines are better positioned to meet the prerequisite requirements for courses in the minor and ASI Mechanical Engineering program. (See Minor/ASI section of the Bulletin for all requirements for a minor/ASI at CSM.)

For an Area of Special Interest in Mechanical Engineering, the student must complete the following 12 credits hours:

MEGN212	INTRODUCTION TO SOLID MECHANICS	3.0
MEGN261	THERMODYNAMICS I	3.0
MEGN315	DYNAMICS	3.0
MEGN351	FLUID MECHANICS	3.0

For a Minor in Mechanical Engineering, the student must complete a minimum of 18 credits from the following:

1. Required Courses (choose three, 9 credits)		
MEGN212	INTRODUCTION TO SOLID MECHANICS	3.0
MEGN261	THERMODYNAMICS I	3.0
MEGN315	DYNAMICS	3.0
MEGN351	FLUID MECHANICS	3.0
2. Tracks (choose one track):		
Robotics, Automation & Design Track (9 credits)		
MEGN324	INTRODUCTION TO FINITE ELEMENT ANALYSIS	3.0
MEGN481	MACHINE DESIGN	3.0
MEGN381	MANUFACTURING PROCESSES	3.0
or MEGN441	INTRODUCTION TO ROBOTICS	
or MEGN416	ENGINEERING VIBRATION	
or MEGN485	MANUFACTURING OPTIMIZATION WITH NETWORK MODELS	
Solid Materials Track (9 credits)		
MEGN324	INTRODUCTION TO FINITE ELEMENT ANALYSIS	3.0
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
MEGN416	ENGINEERING VIBRATION	3.0
Thermal-Fluids Track (9 credits)		
MEGN451	AERODYNAMICS	3.0
MEGN461	THERMODYNAMICS II	3.0
MEGN471	HEAT TRANSFER	3.0

Biomechanical Engineering Minor

General Requirements

To obtain a Biomechanical Engineering Minor, students must take at least 11.0 credits from the courses listed below. Fundamentals of Biology I (CBEN110) and Introduction to Biomechanical Engineering (MEGN330) are required (7.0 credits). Three more courses may be chosen from the proposed list of electives. The list of electives will be modified as new related courses become available.

Required Courses (7.0 credits)

CBEN110	FUNDAMENTALS OF BIOLOGY I	4.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0

Biomechanical Engineering Elective Courses

MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
or MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT	
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING	3.0
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS	3.0
MEGN536	COMPUTATIONAL BIOMECHANICS	3.0
MEGN537	PROBABILISTIC BIOMECHANICS	3.0
MEGN553	COMPUTATIONAL FLUID DYNAMICS	3.0
MEGNX98/X99	SPECIAL TOPICS *	3.0
MTGN472	BIOMATERIALS I	3.0
or MTGN572	BIOMATERIALS	
MTGN570	BIOCOMPATIBILITY OF MATERIALS	3.0
CBEN311	INTRODUCTION TO NEUROSCIENCE	3.0
CBEN304	ANATOMY AND PHYSIOLOGY	3.0
CBEN305	ANATOMY AND PHYSIOLOGY LAB	1.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN454	APPLIED BIOINFORMATICS	3.0
or CBEN554	APPLIED BIOINFORMATICS	
MATH431	MATHEMATICAL BIOLOGY	3.0
PHGN433	BIOPHYSICS	3.0
CBEN120	FUNDAMENTALS OF BIOLOGY II	4.0

* As the content of these courses varies, the course must be noted as relevant to the biomechanical engineering minor.

Minor and ASI in Additive Manufacturing

The interdisciplinary Additive Manufacturing program will prepare undergraduates to meet the challenges of careers in additive manufacturing. Undergraduate students have the following degree options:

- Area of Special Interest (12 credits)
  - Requirements: AMFG401 and 9 credits of electives (see Table 1)
- Minor (18 credits)
  - Requirements: AMFG401 and 15 credits of electives (see Table 1)

Table 1: Undergraduate elective courses, listed by specialty area (AMFG531, AMFG 511 and FEGN 526 require approval by appropriate program directors)

Additive Manufacturing of Structural Materials		
MEGN381	MANUFACTURING PROCESSES	3.0
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
AMFG421	DESIGN FOR ADDITIVE MANUFACTURING	3.0
AMFG531	MATERIALS FOR ADDITIVE MANUFACTURING	3.0
AMFG498	SPECIAL TOPICS IN ADVANCED MANUFACTURING	1-6
AMFG511	DATA DRIVEN ADVANCED MANUFACTURING	3.0
FEGN525	ADVANCED FEA THEORY & PRACTICE	3.0
FEGN526	STATIC AND DYNAMIC APPLICATIONS IN FEA	3.0

Aerospace Engineering Minor

The Aerospace Engineering minor includes six required courses listed below. Four of the courses currently exist in the mechanical engineering curriculum, and two are new courses. Courses in this minor, some developed in conjunction with industry, will help prepare Mines students for a career in aerospace industries.

SPRS498	INTRO TO SPACE EXPLORATION & RESOURCES	3.0
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MEGN451	AERODYNAMICS	3.0
MEGN453	AEROSPACE STRUCTURES	3.0
MEGN454	ORBITAL MECHANICS	
MEGN456	SPACE OPERATIONS AND MISSION DESIGN	3.0
Total Semester Hrs		**15.0**

ASI in Aerospace Engineering

For an Area of Special Interest in Aerospace Engineering, the student must complete a minimum of 12 credits from the following:

MEGN451	FLUID MECHANICS II - AERODYNAMICS	3.0
MEGN471	HEAT TRANSFER	3.0
MEGN414	MECHANICS OF COMPOSITE MATERIALS	3.0
MEGN453	AEROSPACE STRUCTURES	3.0

Courses

MEGN200. INTRODUCTION TO MECHANICAL ENGINEERING: PROGRAMMING AND HARDWARE INTERFACE. 3.0 Semester Hrs.
This course introduces programming skills using Matlab as a means to collect and analyze data and utilizes Arduinos as a platform for prototyping circuits and designs. This course reinforces the engineering design process through problem definition and identifying constraints and criteria, encouraging multiple solutions, and introducing analysis in design through prototyping. Prerequisite: EDNS155 or HNRS105 or HNRS115 or HNRS198, CSCI101, CSCI102.
Course Learning Outcomes

- 1. Demonstrate programming logic through use of Matlab
- 2. Compose software programs (in Arduino) to solve engineering problems
- 3. Demonstrate hardware and software interface
- 4. Use Arduinos to produce a working prototype
- 5. Design simple circuits in use with Arduinos
- 6. Document problem definition, user needs, and project requirements through clear constraints and criteria
- 7. Create a working prototype and validate through testing
- 8. Compute the probability of a data set using MATLAB
- 9. Calculate statistics of a data set using MATLAB
- 10. Demonstrate technical writing and professional documentation of projects
- 11. Verbally communicate design solutions
- 12. Collaborate with team members to solve a design problem and produce a protoytpe.

MEGN201. INTRODUCTION TO MECHANICAL ENGINEERING: DESIGN & FABRICATION. 3.0 Semester Hrs.
This course reinforces basic drawing skills from Cornerstone Design, introduces SolidWorks tools to advance modeling skills, introduces machine shop skills (including safety and use of mill, lathe and CNC) and introduces GDnT practices important in fabrication and manufacturing, and prob-stats relevant to manufacturing. 3 hours lecture; 3 semester hours. Prerequisite: EDNS151 or EDNS155; HNRS105 or HNRS198A.
Course Learning Outcomes

- 1. Demonstrate basic drawing skills in orthographic views
- 2. Use SolidWorks to design an object and/or product
- 3. Demonstrate good GDnT practice in both documentation and prototypes
- 4. Employ general shop safety skills
- 5. Demonstrate manual use of mill - lathe - CNC
- 6. Apply statistical methods relative to manufacturing and GDnT
- 7. Design (prototype) a part for manufacturability (tolerances, assembly, clearances, etc.)
- 8. Demonstrate ability to implement quality control on designed parts
- 9. Communicate technical information through drawings and letter of intent
- 10. Collaborate with team members to produce a part/product.

MEGN212. INTRODUCTION TO SOLID MECHANICS. 3.0 Semester Hrs.
Equivalent with MEGN312,
This course introduces students to the principles of Solid Mechanics. Upon completion, students will be able to apply Solid Mechanics theories

to analyze and design machine elements and structures using isotropic materials. The skills and knowledge learned in this course form the required foundation for Intro to Finite Element Analysis, Advanced Mechanics of Material, Machine Design and other advanced topics in engineering curricula. Practically, it enables students to solve real-world mechanical behavior problems that involve structural materials. This courses places an early focus on ensuring students have mastered the creation of free body diagrams given a mechanical system, then moves on to introduce and reinforce learning of stress and strain transformations, and failure theories. In practicing this knowledge, students will be able to analyze and design machine elements and structures of homogenous and heterogeneous geometries under axial, torsional, bending, transverse shear, internal pressure loads, and non-uniform loads. Students will be able to quantitatively communicate the outcomes. May not also receive credit for CEEN311. Prerequisite: CEEN241 (C- or better).

Course Learning Outcomes

- 1. Use free body diagrams in the analysis of structures
- 2. Apply principles of Solid Mechanics to the analysis of elastic structures under simple, combined, and thermal loading
- 3. Use Mohr's circle and stress transformation equations
- 4. Use stress elements to show stress state at a point
- 5. Use failure theories to assess safety of design
- 6. Effectively communicate the outcomes of analysis and design problems

MEGN261. THERMODYNAMICS I. 3.0 Semester Hrs.

This course is a comprehensive treatment of thermodynamics from a mechanical engineering point of view. Topics include: Thermodynamic properties of substances inclusive of phase diagrams, equations of state, internal energy, enthalpy, entropy, and ideal gases; principles of conservation of mass and energy for steady-state and transient analyses; First and Second Law of thermodynamics, heat engines, and thermodynamic efficiencies; Application of fundamental principles with an emphasis on refrigeration and power cycles. May not also receive credit for CBEN210. Prerequisite: MATH213 (C- or better).

Course Learning Outcomes

- 1. Identify the boundary of a system by drawing a control surface and label the transfer of mass and energy across the control surface for a given process.
- 2. Apply balance equations (mass, energy, and entropy) to analyze steady and unsteady processes, relating a system's inputs and outputs (heat, work, and mass transfer) and material properties (temperature, pressure, etc.) with one another.
- 3. Determine the properties of pure substances using equations of state, property tables, software tools, or thermodynamic surfaces, choosing an appropriate method.
- 4. Use the 1st and 2nd law of thermodynamics to identify possible and impossible processes.
- 5. Apply the concept of isentropic efficiency to compare actual and ideal devices.
- 6. Use the concepts of thermal efficiency and coefficient of performance to analyze the performance of power cycles (power plants and internal combustion engines), and assess the performance by comparing to other cycles, to theoretical limits, and to practical material and economic limitations.
- 7. Represent thermodynamic processes in multiple formats, by drawing process schematics, drawing thermodynamic property (P-v and T-s) diagrams, applying balance equations, and writing for diverse audiences (science and non-science).
- 8. Design and analyze thermodynamic systems (cycles and other devices) to meet heating, cooling, and/or power needs for a specified application.

MEGN298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN300. INSTRUMENTATION & AUTOMATION. 3.0 Semester Hrs.

This course will explore instrumentation and automation of electro-mechanical systems. Students will utilize LabView and electro-mechanical instrumentation to solve advanced engineering problems. Class activities and projects will highlight the utility of LabView for real-time instrumentation and control. Prerequisite: MEGN200 (C- or better). Corequisite: MEGN201.

Course Learning Outcomes

- 1. Recognize the strengths and limitations of the software and hardware platforms for instrumentation, data collection and analysis
- 2. Create customized instrumentation systems and user interfaces
- 3. Explore software architectures for instrumentation and control
- 4. Explore various sensor and actuator technologies
- 5. Apply probability and statistics in large data sets
- 6. Design an instrumentation system for a specific application
- 7. Communicate testing procedures and analysis in a technical report
- 8. Discuss hardware platforms for embedded industrial instrumentation and control, including NI myRIO and CompactRIO

MEGN301. MECHANICAL INTEGRATION & DESIGN. 3.0 Semester Hrs.

Students will utilize the engineering design process and knowledge in systems level design to produce a mechanical product/process. Students will reverse engineer a product/process to emphasize the steps in the design process. Students will select a longer course project, which is intended to reinforce engineering skills from other courses. The project topics would parallel one of the four research disciplines in ME, and students would be able to choose a topic pathway that emphasizes opportunities for mechanical engineering graduates. Prerequisite: MEGN200 (C- or better), MEGN201 (C- or better), MEGN300 (C- or better). Corequisite: MEGN 381.

Course Learning Outcomes

- 1. apply the engineering design process, from recognition of client needs to release of a fully-tested mechanical/electromechanical product
- 2. apply a systems-level approach in the design of a product
- 3. incorporate regulatory requirements and/or standards and additional realistic constraints pertinent to mechanical/electromechanical devices, products or systems into the design process

- 4. apply technical knowledge in engineering, mathematics, and the sciences to design and benchmark mechanical/electromechanical products
- 5. use modern engineering software tools in mechanical product design (e.g. Matlab, SolidWorks, or LabView)
- 6. demonstrate use of statistics and probability in the analysis of test results
- 7. professionally document and communicate design efforts

MEGN315. DYNAMICS. 3.0 Semester Hrs.
This course will cover particle kinematics (including 2-D motion in x-y coordinates, normal-tangential coordinates, & polar coordinates), rigid body kinematics (Including relative velocities and accelerations), rigid body kinetics (including the equation of motion, work and energy, linear impulse-momentum, & angular momentum), and introduction to vibrations. Prerequisite: CEEN241 (C- or better) and MATH225 (C- or better). MATH225.
Course Learning Outcomes

- 1. Understand the basic principles of particle dynamics.
- 2. Understand the basic principles of planar rigid body dynamics.
- 3. Demonstrate the ability to apply the principles of dynamics to solve basic engineering problems with analytic and numerical techniques.

MEGN324. INTRODUCTION TO FINITE ELEMENT ANALYSIS. 3.0 Semester Hrs.
Equivalent with MEGN424,
This course aims to teach basic proficiency with Finite Element Analysis (FEA), which is the most widely used computer aided engineering tool in industry, academia, and government. Fundamentals of FEA theory are introduced, but the majority of the course is spent learning practical skills with commercial FEA software. Students will work interactively with the instructor and with their peers to complete hands-on FEA examples based primarily on problems in structural mechanics. Applications of FEA for heat conduction, natural frequency analysis, and design optimization are covered briefly. The course will conclude with a mini project on which students use FEA skills for engineering analysis and design. The importance of verification and validation (V&V) for critical evaluation of FEA predictions is emphasized, and students will make frequent use of statics and solid mechanics principles to corroborate their FEA results. Prerequisite: MEGN212 (C- or better) or CEEN311 (C- or better).
Course Learning Outcomes

- Understand the basic concepts of th e global stiffness force-displacement matrix equations in the displacement finite element method.
- Use a commercial finite element software package (SW Simulation), associated CAD modeling software (SolidWorks) and an engineering math softwa re (MATH CAD) to perform engineering analysis.
- Apply classical engineering methods such as statics and mechanics of materials to check whether the results of a finite element analysis are sensible.
- Apply finite element analysis in the engineering design process. For example, design a simple truss structure and perform finite element analyses to determine the dimensions of the structural members based on specified design constraints.
- Write clear and concise technical memoranda and reports describing the results of an engineering analysis and their use in an engineering design if appropriate.

MEGN330. INTRODUCTION TO BIOMECHANICAL ENGINEERING. 3.0 Semester Hrs.
The application of mechanical engineering principles and techniques to the human body presents many unique challenges. The discipline of Biomedical Engineering (more specifically, Biomechanical Engineering) has evolved over the past 50 years to address these challenges. Biomechanical Engineering includes such areas as biomechanics, biomaterials, bioinstrumentation, medical imaging, and rehabilitation. This course is intended to provide an introduction to, and overview of, Biomechanical Engineering and to prepare the student for more advanced Biomechanical coursework. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply various mechanical engineering principles to the human body. Prerequisite: CEEN241.
Course Learning Outcomes

- Understand the basic concepts in applying material learned in other Mechanical Engineering classes (statics, mechanics of materials) to analysis of the human body

MEGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I,II,S) Supervised, full-time engineering- related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Engineering Division Faculty Co-op Advisor prior to enrolling to clarify the educational objectives for their individual Co-op program. 3 semester hours credit will be granted once toward degree requirements. Credit earned in EGGN340, Cooperative Education, may be used as free elective credit hours or a civil specialty elective if, in the judgment of the Co-op Advisor, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives or civil electives requires the student to submit a 'Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements' form obtained from the Career Center to the Engineering Division Faculty Co-op Advisor.Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00.

MEGN351. FLUID MECHANICS. 3.0 Semester Hrs.
This course will cover principles of fluid properties, fluid statics, control-volume analysis, Bernoulli equation, differential analysis and Navier-Stokes equations, dimensional analysis, internal flow, external flow, open-channel flow, and turbomachinery. May not also receive credit for CEEN310 or PEGN251. Prerequisite: CEEN241 with a grade of C- or better or MNGN317 with a grade of C- or better.
Course Learning Outcomes

- Solve mass conservation, momentum, and energy equations for steady-state fluid-flow systems (control-volume analyses).
- Apply differential conservation-of-mass and linear-momentum equations and material derivatives to the solution of flow problems (differential analysis).
- Establish non-dimensional groupings of fluid properties, and apply them in the design of experiments that scale between models and prototypes (dimensional analysis).
- Model fully developed laminar and turbulent pipe flow systems (internal flow).
- Develop the relationships for lift and drag on bodies moving through a fluid (external flow).
- Convey understanding of course materials through homework assignments and exams.

- Distinguish what physical aspects are most critical and have greatest impact on a given problem and design.
- Establish an intuition of fluid behavior, analyze its effects in a given problem, and apply your knowledge to propose design solutions.

MEGN381. MANUFACTURING PROCESSES. 3.0 Semester Hrs.
Equivalent with MEGN380,
Manufacturing Processes is a survey course, that introduces a wide variety of traditional and advanced manufacturing processes with emphasis on process selection and hands-on experiences. Students are expected to have basic knowledge in material science, basic machining and GD&T before entering the class. Throughout the course students analyze the relationships between material properties, process variables and product functionality. Students design and evaluate processes for identifying value while eliminating waste using learned skill-sets including lean methodologies, six-sigma and statistical process control. Quality, cost, standards and ethics related to manufacturing are discussed throughout the semester. Prerequisite: MEGN201 with a grade of C- or better and MTGN202. MEGN212.
Course Learning Outcomes

- Understand basic manufacturing processes and how they apply to designed parts, materials and assemblies
- Be able to use design for manufacturability concepts when designing parts

MEGN385. INTRODUCTION TO CNC AND CAM PROGRAMMING. 1.0 Semester Hr.
This course will guide students through the process of machining parts on a 3-axis CNC (computer numeric-controlled) milling machine. The code for the CNCs will be generated with a CAM (computer aided-machining) program. We will machine parts with multiple setups and discuss strategies for complicated parts. Prerequisite: MEGN 201.
Course Learning Outcomes

- 1. Utilize CAM programming to create the machine code for CNCs.
- 2. Apply milling tool datasheets to optimize the machining performance.
- 3. Select tooling based on the characteristics of specific tools and material setups for creating unique part features.
- 4. Evaluate and select tool operations for efficient material removal and precisely detailed part features.
- 5. Set up and operate 3 axis vertical CNC milling machines
- 6. Design parts for CNC manufacturability
- 7. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

MEGN391. INTRODUCTION TO AUTOMOTIVE DESIGN. 3.0 Semester Hrs.
Automotive engineering involves the design and implementation of complex systems. This course introduces students to the workings of the automotive industry, including its history, future, and the stakeholders that determine its direction. The course also covers the major vehicle subsystems and their functionality, interfaces, components, and recent advancements. Students will apply theoretical and practical systems engineering principles to perform a design of a vehicle subsystem to gain perspective of how the automotive design process is executed and how it fits into the larger scope of the automotive industry. Prerequisite: MEGN200 with of grade C- or better.
Course Learning Outcomes

- 1. Work on a successful design team to create a design for a significant mechanical, electrical, structural, or industrial system.
- 2. Identify performance, manufacturing, and safety standards, on system and subsystem levels, that will lead to design success.
- 3. Create design concepts and alternatives, and apply selection criteria.
- 4. Identify and solve design-related engineering analysis problems.
- 5. Conduct cost and safety analyses.
- 6. Communicate a design process and its results by written report, technical illustration, and oral presentation.
- 7. Manage a design project, including: making and keeping schedules; allocating and utilizing resources; specifying and acquiring components; meeting budgets and deadlines.

MEGN398. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN408. INTRODUCTION TO SPACE EXPLORATION. 3.0 Semester Hrs.
Overview of extraterrestrial applications of science and engineering by covering all facets of human and robotic space exploration, including its history, current status, and future opportunities in the aerospace and planetary science fields. Subtopics include: the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), current research, missions, and projects, the international and commercial perspectives, and discussion of potential career opportunities. This seminar style class is taught by CSM faculty, engineers and scientists from space agencies and research organizations, aerospace industry experts, and visionaries and entrepreneurs of the private space commerce sector.

MEGN412. ADVANCED MECHANICS OF MATERIALS. 3.0 Semester Hrs.
This Advanced Mechanics of Materials course builds upon the learning outcomes of the pre-requisite Mechanics of Materials (Solid Mechanics) course to teach students the fundamentals of elastic deformations. Introduction to energy methods, strain and stress transformations, constitutive relations for isotropic and orthotropic materials, and to fracture mechanics is realized through theory development, application examples, and numerical solutions. Knowledge from this course will enable students to work on variety of engineering applications in Mechanical, Materials, Aerospace, Civil and related engineering fields. Prerequisite: MEGN212 (C- or better) or CEEN311 (C- or better).
Course Learning Outcomes

- 1. Define, and apply, displacement-strain relationships. Calculate principal strains, maximum shear strain in 2D and 3D.
- 2. Use gauges and rosettes for strain measurements.
- 3. Find stresses at a point, principal stresses and max shear stress.

- 4. Define, and apply, the generalized form of Hooke's Law for isotropic materials.
- 5. Define, and apply, the generalized form of Hooke's Law for orthotropic materials.
- 6. Apply theories of failure for ductile and brittle materials.
- 7. Use energy methods to compute strain energy, determine the effect of impact loading, determine displacements due to single or multiple loads, and solve statically indeterminate problems.
- 8. Define crack modes and stress intensity factor. Estimate stresses in the "near-field".
- 9. Apply plastics zone size correction to the crack length.
- 10. Explain, and apply, the design philosophy given by the relationship between material property (fracture toughness), design stress, allowable flow size or NDT flaw detection.
- 11. Estimate fatigue life of cracked and un-cracked components.

MEGN414. MECHANICS OF COMPOSITE MATERIALS. 3.0 Semester Hrs.
Introductory course on the mechanics of fiber-reinforced composite materials. The focus of the course is on the determination of stress and strain in a fiber-reinforced composite material with an emphasis on analysis, design, failure by strength-based criteria, and fracture of composites. Anisotropic materials are discussed from a general perspective then the theory is specialized to the analysis of fiber-reinforced materials. Both thermal and hygroscopic sources of strain are introduced. Classical laminated plate theory is next developed, and design of laminated composite structures is introduced. The analysis of helically reinforced composite tubes concludes the course. Prerequisite: MEGN212 (C- or better).
Course Learning Outcomes

- 1. Apply concepts of the mechanics of composite materials to the analysis of fiber-reinforced lamina
- 2. Use transformation equations to analyze fiber-reinforced lamina with arbitrary fiber orientation
- 3. Predict overall elastic properties of a fiber-reinforced lamina from micromechanics models
- 4. Choose and apply an appropriate failure criterion to assess safety of fiber-reinforced lamina
- 5. Apply classical laminated plate theory to calculate stresses in laminated composites
- 6. Design a laminated plate structure given mechanical and thermal loads
- 7. Determine the stress state in helically reinforced composite tubes

MEGN416. ENGINEERING VIBRATION. 3.0 Semester Hrs.
This course introduces linear theory of mechanical vibrations as applied to single- and multi-degree-of-freedom systems. Specifically, students learn to analyze and measure free and forced vibrations of spring-mass-damper systems in response to different types of loading including harmonic, impulse, and general transient loading. Force balance and energy methods are introduced as means to create models of vibrating mechanical components. Ultimately, students learn to apply these theories to design vibration isolators and dampers for machines subject to translational and rotational vibrations, including machines with rotating unbalances and two or more vibrating masses. Prerequisite: MEGN315 (C- or better).
Course Learning Outcomes

- ability to apply knowledge of mathematics, science, and engineering
- ability to identify, formulate, and solve engineering problems

MEGN417. VEHICLE DYNAMICS & POWERTRAIN SYSTEMS. 3.0 Semester Hrs.
This course offers an introduction to automotive engineering with a focus on vehicle design, suspension, powertrain and aerodynamics. The course is designed to introduce students to both theoretical and practical concepts of vehicle design with applications in increasing fuel efficiency and vehicle performance. The study of automotive engineering is of increasing importance as new technologies emerge and advances continue to be made to existing designs to create the ultimate driving experience; while having minimal impact on the environment by reducing tailpipe gas emissions, noise pollution, and waste material during manufacturing of new vehicles. Prerequisite: MEGN315, MEGN324, MEGN261.
Course Learning Outcomes

- Students will use fundamental lateral and longitudinal dynamic equations to design the proper suspension setup for various road and racing scenarios
- Students will be able to identify key components of a vehicle's suspension and powertrain system and describe their respective function to the performance of the vehicle
- Students will perform relevant calculations and numerical modeling related to vehicle design and handling characteristics (e.g. roll, over/under-steer)
- Students will solve basic engine performance calculations related to power and torque and determine which final drive ratio is adequate for certain racing applications

MEGN430. MUSCULOSKELETAL BIOMECHANICS. 3.0 Semester Hrs.
This course is intended to provide mechanical engineering students with a second course in musculoskeletal biomechanics. At the end of the semester, students should have in-depth knowledge and understanding necessary to apply mechanical engineering principles such as statics, dynamics, and mechanics of materials to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. 3 hours lecture; 3 semester hours. Prerequisite: MEGN212 OR CEEN311; MEGN315; MEGN330 (C- or better).
Course Learning Outcomes

- Understand advanced concepts in applying material learned in other Mechanical Engineering classes (statics, mechanics of materials) to analysis of the human body

MEGN435. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.
Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties, interactions with the environment, and computational optimization to construct detailed computer models and simulations of human movement. Prerequisite: MEGN315 with a grade C- or better, MEGN330 with grade of C- or better.

MEGN441. INTRODUCTION TO ROBOTICS. 3.0 Semester Hrs.
Overview and introduction to the science and engineering of intelligent mobile robotics and robotic manipulators. Covers guidance and force sensing, perception of the environment around a mobile vehicle, reasoning about the environment to identify obstacles and guidance path features and adaptively controlling and monitoring the vehicle health. A

lesser emphasis is placed on robot manipulator kinematics, dynamics, and force and tactile sensing. Surveys manipulator and intelligent mobile robotics research and development. Introduces principles and concepts of guidance, position, and force sensing; vision data processing; basic path and trajectory planning algorithms; and force and position control. EENG307 is recommended to be completed before this course. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: (MEGN200 or CSCI261 or CSCI200) and (EENG281 or EENG282 or PHGN215).

Course Learning Outcomes

- To be completed at a later time (course coordinator on leave)

MEGN451. AERODYNAMICS. 3.0 Semester Hrs.

Review of elementary fluid mechanics and engineering; Two-dimensional external flows, boundary layers, and flow separation; Gas dynamics and compressible flow: Isentropic flow, normal and oblique shocks, rocket propulsion, Prandtl-Meyer expansion fans; Application of computational fluid dynamics. Prerequisite: MEGN351(C- or better).

Course Learning Outcomes

- • Apply control-volume conservation-of-mass, linear-momentum, angular-momentum and energy equations to the solution of flow problems.
- • Apply differential conservation-of-mass and linear-momentum equations and to the solution of flow problems.
- • Understand development and analysis of boundary layers.
- • Comprehend analysis of compressible and supersonic flows, including shock waves.
- • Understand theory and application of turbomachinery.

MEGN452. INTRO TO SPACE EXPLORATION AND RESOURCES. 3.0 Semester Hrs.

Overview of human and robotic space exploration, including its history, current status, and future opportunities. Course topics cover the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), the aerospace industry, space commerce and law, and the international space activity. Emphasis is placed on the field of space resources, including their identification, extraction, and utilization to enable future space exploration and the new space economy.

MEGN453. AEROSPACE STRUCTURES. 3.0 Semester Hrs.

This course covers advanced mechanics of materials relevant to the analysis and design of aerospace structures. Focused topics include multiaxial stress states, nonsymmetric loading, composites, airframe loads, and shear flow emphasizing lightweight, often thin-walled structures common in aerospace applications. Other advanced topics will be introduced, time permitting. Prerequisite: MEGN212.

Course Learning Outcomes

- Understand physical & mathematical relationship(s) between displacement, stress, and strain.
- Apply concepts of compatibility, equilibrium, and constitutive relations on geometries preva- lent in aerospace structural analysis.
- Distinguish appropriate failure criteria and assumptions under various airframe loading con- ditions.
- Solve basic boundary value problems on plane stress, plane strain, torsion, beam bending, and shear flow for thin-walled structures.
- Gain team experience through a design/build/test project that utilizes concepts learned in the course

MEGN454. ORBITAL MECHANICS. 3.0 Semester Hrs.

Orbital Mechanics introduces students to the dynamics that govern motion of bodies in space and the utilization of these dynamics in spacecraft orbit and trajectory design. This course develops the mathematical foundation of propagating, describing, and manipulating the motion of a spacecraft in orbit. Throughout the semester students will script their own (basic) universe simulators to examine the various forces and geometries in orbit. Prerequisite: MEGN315.

Course Learning Outcomes

- 1. Calculate the position of a body (satellite) under Keplerian dynamics as a function of time.
- 2. Interpret the state and orbit type of a body (satellite) in an elliptical orbit using classic orbital elements.
- 3. Implement a state propagator for a body (satellite) in an elliptical orbit in Keplerian dynamics and under common perturbation models.
- 4. Calculate the impulsive delta-V maneuvers required to manipulate a body's (satellite) orbit state in common transfers

MEGN455. AEROSPACE SYSTEMS ENGINEERING. 3.0 Semester Hrs.

An introduction to aerospace systems engineering. This course is designed for students to explore both theoretical and practical systems engineering concepts and knowledge using examples drawn from the aerospace and defense industries. Starting with the systems engineering v model, students will gain hands on experience working with modern Model Based Systems Engineering (MBSE) software and develop systems engineering deliverables such as Concepts of Operations (ConOps) documents as part of a semester long project. Prerequisite: Best taken just before Senior Design or as a co-req with Senior Design I.

Course Learning Outcomes

- 1. Students will be able to describe the most important systems engineering standards and best practices as well as newly emerging approaches using the systems engineering V-model.
- 2. Students will be able to write and decompose multi-level system requirements
- 3. Students will learn applied model-based systems engineering and demonstrate their understanding using an industry standard Model Based System Engineering (MBSE) software
- 4. Students will develop and demonstrate applied model-based engineering, through development of support document for their semester long project
- 5. Students will demonstrate their understanding of system mission and operating environments through the develop of a concept of operations (ConOps) document
- 6. Students will be able to identify system risks and opportunities and appropriately rank and defend their approach
- 7. Students will demonstrate their understanding of interfaces, constraints, and system specifications/figures of merit/technical performance metrics/measure of performance through the drafting of an Interface Control Document (ICD)
- 8. Students will visually communicate their understanding of project execution via the develop of a system engineering management plan (SEMP)
- 9. Students will demonstrate understanding of the value of appropriate test procedures and test plans through the development of a project test plan

- 10. Students will be able to differentiate between validation and verification in the systems engineering context

MEGN456. SPACE OPERATIONS AND MISSION DESIGN. 3.0 Semester Hrs.

Space Operations and Mission Design (SOMD) is a course for upper level undergraduate and graduate students at Mines who are interested in expanding their knowledge of astrodynamics, spacecraft and space mission design, project management, and systems engineering.
Upon leaving the course, students will have a head start on potential internships/careers in the aerospace industry armed with key vocabulary and terms, experience with industry relevant software and tools, and core skills and knowledge gained through practice addressing real-world problems in the space domain.

Course Learning Outcomes

- Students shall develop and defend their mission risk/opportunity assessment, applying risk matrices and mitigation plans as tools.
- Students shall collaboratively define, design, and plan a simulated mission considering stakeholders, associated space laws/regulations, and resource management.
- Students shall develop and assess technical resource budgets. Examples include: mass, power, thermal, telecommunications, and data volume.
- Students shall apply appropriate terminology associated with space flight operations
- Students shall execute space mission planning principles such as: Orbit determination, Orbital maneuvering, Launch windows, Orbital rendezvous, and Proximity operations
- Students shall analyze orbital motion by visualizing from both inertial and relative perspectives
- Students shall synthesize the effects of launch, orbital maneuvers, rendezvous, and proximity operations on space situational awareness and space mission design and operations

MEGN461. THERMODYNAMICS II. 3.0 Semester Hrs.

This course extends the subject matter of Thermodynamics I (MEGN261) to include the study of exergy, ideal gas mixture properties, psychrometrics and humid air processes, chemical reactions, and the 1st, 2nd and 3rd Laws of Thermodynamics as applied to reacting systems. Chemical equilibrium of multi-component systems, and simultaneous chemical reactions of real combustion and reaction processes are studied. Concepts of the above are explored through the analysis of advanced thermodynamic systems. 3 hours lecture; 3 semester hours. Prerequisite: MEGN351 (C- or better), MEGN261 (C- or better).

Course Learning Outcomes

- Ability to solve and analyze physical processes that include: Exergy (2nd Law) analysis of energy systems • Mixtures of ideals gases • Psychrometrics including mass and energy balances of humid air processes • Chemical reactions, combustion, and fuel/air stoichiometry • Phase and chemical equilibrium • Simultaneous reactions and Ionization • Thermodynamics of compressible flow in nozzles including shock • Advanced thermodynamic cycles including cascaded and absorption refrigeration systems, cryogenics, and gas turbine and combined cycles.

MEGN465. ELECTRIC VEHICLE POWERTRAIN SYSTEMS. 3.0 Semester Hrs.

In the fast-evolving world of sustainable transportation, it is essential for engineers in the automotive industry to understand energy conversion, storage, utilization, and optimization of vehicle powertrains. Electric Vehicle Powertrain Systems (EVPS) is designed to provide students with a comprehensive understanding of the essential powertrain components in battery-electric vehicles (BEVs) including motors, controllers, and battery packs. Through a combination of theoretical modeling and hands-on projects, students will gain knowledge and skills in powertrain system design to achieve vehicle objectives, encompassing energy analysis, power requirements, and efficiency considerations. The course will also explore the state-of-the-art in safety measures, management strategies, control systems, charging/balancing techniques, and State of Charge (SOC)/State of Health (SOH) estimation for EV battery packs. Prerequisite: MEGN300 or EEGN 282.

Course Learning Outcomes

- 1. Articulate the functions and interrelationships of the core powertrain components in electric vehicles, including the motor, controller, and battery pack
- 2. Design a vehicle powertrain architecture and select powertrain components that meet the overarching goals of an electric vehicle, incorporating top-level requirements such as energy use, power output, and efficiency optimization
- 3. Explain the operating principles and fundamental characteristics of Li-ion batteries using underlying electrochemical processes and implement them in an equivalent circuit battery cell model
- 4. Apply experimental methods used to characterize the performance of Li-ion cells in automotive applications, while elucidating the principles and significance of these techniques in assessing battery behavior and performance.
- 5. Critically assess and compare the state of the art in safety protocols, management strategies, control systems, and charging/balancing techniques for battery packs in electric vehicle powertrain systems.
- 6. Devise a functional design for a battery pack tailored to the specific requirements and constraints of a full-size electric vehicle, integrating considerations such as energy storage capacity, thermal management, safety measures, and space utilization

MEGN466. INTRODUCTION TO INTERNAL COMBUSTION ENGINES. 3.0 Semester Hrs.

Introduction to Internal Combustion Engines (ICEs); with a specific focus on Compression Ignition (CI) and Spark Ignition (SI) reciprocating engines. This is an applied thermo science course designed to introduce students to the fundamentals of both 4-stroke and 2-stroke reciprocating engines ranging in size from model airplane engines to large cargo ship engines. Course is designed as a one-semester course for students without prior experience with IC engines, however, the course will also include advanced engine technologies designed to deliver more horsepower, utilize less fuel, and meet stringent emission regulations. Discussion of advancements in alternative fueled engines will be covered as well. This course also includes an engine laboratory designed to provide hands-on experience and provide further insight into the material covered in the lectures. Prerequisite: MEGN351 with a grade of C- or better, MEGN261 with a grade of C- or better. Co-requisite: MEGN471.

Course Learning Outcomes

- ABET j and k outcomes will be measured through homework assignments and projects.

MEGN467. PRINCIPLES OF BUILDING SCIENCE. 3.0 Semester Hrs.

This course covers the fundamentals of building heating, ventilation, and air conditioning (HVAC) systems and the use of numerical heat and moisture transfer models to analyze or design different building envelope and HVAC systems. Prerequisite: MEGN351 with a grade of C- or better, MEGN261 with a grade of C- or better.

Course Learning Outcomes

- 1. Understand and apply fundamental principles to HVAC design
- 2. Describe components in HVAC systems
- 3. Understand how building HVAC loads are calculated and calculate building HVAC loads
- 4. Conduct building energy analyses using computer simulation tools

MEGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CBEN469,MTGN469,

Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisite: MEGN261 with a grade of C- or better or CBEN357 with a grade of C- or better.

MEGN471. HEAT TRANSFER. 3.0 Semester Hrs.

Engineering approach to conduction, convection, and radiation, including steadystate conduction, nonsteady-state conduction, internal heat generation conduction in one, two, and three dimensions, and combined conduction and convection. Free and forced convection including laminar and turbulent flow, internal and external flow. Radiation of black and grey surfaces, shape factors and electrical equivalence. 3 hours lecture; 3 semester hours. Prerequisite: MEGN351 (C- or better), MEGN261 (C- or better), and MATH307.

Course Learning Outcomes

- Outcome 1: Ability to analyze and design heat transfer processes and systems
- Outcome 2: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"

MEGN475. INTRODUCTION TO NUCLEAR ENGINEERING. 3.0 Semester Hrs.

An overview of major concepts and themes of nuclear engineering founded on the fundamental properties of the neutron, and emphasizing the nuclear physics bases of nuclear reactor design and its relationship to nuclear engineering problems. Major topics that introduce fundamental concepts in nuclear engineering include the physics and chemistry of radioactive decay, radiation detection, neutron physics, heat transfer in nuclear reactors, and health physics. Nuclear engineering topics relevant to current events are also introduced including nuclear weapons, nuclear proliferation, and nuclear medicine. Prerequisite: MATH225, PHGN200.

Course Learning Outcomes

- 1) Apply concepts of radioactivity to solve problems
- 2) Relate neutron production and consumption to aspects of the lifecycle of the nuclear fuel and nuclear power production
- 3) Apply the basics of nuclear reactor physics and heat transfer to reactor design and operation
- 4) Understand the biological effects of radiation and use basic radiation shielding equations

MEGN479. OPTIMIZATION MODELS IN MANUFACTURING. 3.0 Semester Hrs.

We address the mathematical formulation and solution of optimization models relevant in manufacturing operations. The types of deterministic optimization models examined include: (i) network models; (ii) linear programs; (iii) integer programs; and, (iv) nonlinear programs. Application areas include scheduling, blending, equipment replacement, logistics and transportation, among other topics. Students learn not only how to mathematically formulate the models, but also how to solve them with a state-of-the-art modeling language (Ampl) and appropriate solver (e.g., Cplex or Minos). Algorithms for each problem class will be briefly discussed.

MEGN481. MACHINE DESIGN. 3.0 Semester Hrs.

In this course, students develop their knowledge of machine components and materials for the purpose of effective and efficient mechanical design. Emphasis is placed on developing analytical methods and tools that aid the decision making process. The course focuses on determination of stress, strain, and deflection for static, static multiaxial, impact, dynamic, and dynamic multiaxial loading. Students will learn about fatigue failure in mechanical design and calculate how long mechanical components are expected to last. Specific machine components covered include shafts, springs, gears, fasteners, and bearings. 3 hours lecture; 3 semester hours. Prerequisite: MEGN315 (C- or better) or PHGN350 (C- or better), and MEGN324 (C- or better).

Course Learning Outcomes

- 1. Use a systematic approach for solving design problems
- 2. Be able to design new systems for current technology

MEGN485. MANUFACTURING OPTIMIZATION WITH NETWORK MODELS. 3.0 Semester Hrs.

Equivalent with EBGN456,

We examine network flow models that arise in manufacturing, energy, mining, transportation and logistics: minimum cost flow models in transportation, shortest path problems in assigning inspection effort on a manufacturing line, and maximum flow models to allocate machine-hours to jobs. We also discuss an algorithm or two applicable to each problem class. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. 3 hours lecture; 3 semester hours. Prerequisite: MATH111, MATH 112.

Course Learning Outcomes

- Mathematically formulate optimization models to reflect real-world manufacturing settings.
- Study algorithms and software to solve associated optimization problems.
- Use skills from other engineering courses to identify manufacutring problems and set them up as optimization models.

MEGN486. LINEAR OPTIMIZATION. 3.0 Semester Hrs.

This course addresses the formulation of linear programming models, linear programs in two dimensions, standard form, the Simplex method, duality theory, complementary slackness conditions, sensitivity analysis, and multi-objective programming. Applications of linear programming models include, but are not limited to, the areas of manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. Prerequisite: MATH332 or EBGN509.

Course Learning Outcomes

- 1. Understand how to formulate linear optimization models.
- 2. Understand how to solve linear optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying linear optimization models and how this affects their ability to be solved.
- 4. Understand sensitivity and post-optimality analysis.

MEGN487. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN587,
This course addresses both unconstrained and constrained nonlinear model formulation and corresponding algorithms (e.g., Gradient Search and Newton's Method, and Lagrange Multiplier Methods and Reduced Gradient Algorithms, respectively). Applications of state-of-the-art hardware and software will emphasize solving real-world engineering problems in areas such as manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with an algorithm such as MINOS) these optimization problems is introduced. Offered every other year. Prerequisite: MATH111.
Course Learning Outcomes

- 1. Understand how to formulate nonlinear optimization models.
- 2. Understand how to solve nonlinear optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying nonlinear optimization models and how this affects their ability to be solved.

MEGN488. INTEGER OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN588,
This course addresses the formulation of integer programming models, the branch-and-bound algorithm, total unimodularity and the ease with which these models are solved, and then suggest methods to increase tractability, including cuts, strong formulations, and decomposition techniques, e.g., Lagrangian relaxation, Benders decomposition. Applications include manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. 3 hours lecture; 3 semester hours. Prerequisite: MATH111, MATH112.
Course Learning Outcomes

- 1. Understand how to formulate linear-integer optimization models.
- 2. Understand how to solve linear-integer optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying linear-integer optimization models and how this affects their ability to be solved.
- 4. Understand decomposition techniques to aid in solution.

MEGN498. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Note that MEGN499 does not count as an MEGN Teachnical Elective, though the course does count as a Free Elective. Prerequisite: Independent Study form must be completed and submitted to the Registrar.

Professor and Department Head

Carl Frick

Emeriti Professors

Joan Gosink

Robert King

Graham G.W. Mustoe

Terry E. Parker

Emeriti Associate Professors

David Munoz

John P.H. Steele

Professors

Mohsen Asle Zaeem

John R. Berger

Robert Braun, Rowlinson Professor of Mechanical Engineering

Cristian V. Ciobanu

Gregory S. Jackson

Robert J. Kee, George R. Brown Distinguished Professor

Alexandra Newman

Brian G. Thomas

Associate Professors

Steven DeCaluwe

Mark Deinert

Veronica Eliasson

Joy Gockel

Owen Hildreth

Leslie Lamberson

Anthony J. Petrella

Andrew Petruska

Jason Porter

Anne Silverman, Rowlinson Associate Professor of Mechanical Engineering

Neal Sullivan

Paulo Tabares-Velasco

Nils Tilton

Garritt Tucker, Director of Graduate Studies - ME

Ruichong "Ray" Zhang

Xiaoli Zhang

Assistant Professor

Andrew Osborne

Professors of Practice

Angel Abbud-Madrid

Craig Brice

Christopher Dreyer

George Sowers

Teaching Professors

Kristine Csavina, Assistant Department Head and Director of Undergraduate Studies - ME

Ventzi Karaivanov

Teaching Associate Professors

Jeff Ackerman

Joel M. Bach

Daniel Blood

Oyvind Nilsen

Derrick Rodriguez

Jeff Wheeler

Teaching Assistant Professors

Brian Donovan

Adam Duran

Stephen Geer

Gary Nave

Kelly Rickey

Polina Ringler

Jim Wong

Affiliate Professor of Mechanical Engineering

Michael Mooney

Research Associate Professors

Sandrine Ricote

Huayang Zhu

Research Assistant Professors

Ankit Gupta

Carolina Herradon Hernandez

Garrison Hommer

Xingchao Wang

Metallurgical and Materials Engineering

Degrees Offered

- Bachelor of Science in Metallurgical and Materials Engineering
- Bachelor of Science in Ceramic Engineering

Program Description

The Bachelor of Science in Metallurgical and Materials Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission’s General Criteria and Program Criteria for Materials (1), Metallurgical (2), Ceramics (3), and Similarly Named Engineering Programs.

Metallurgical and Materials Engineering play a major role in the development, utilization, and advancement of technology in every engineering discipline and on a broader scale – society’s way of life. The department of Metallurgical & Materials Engineering offers two programs united in core beliefs to provide undergraduates with the fundamental knowledge associated with materials processing and manufacturing in the context of sustainability, material properties, and materials selection and application. Graduates of either program will have the necessary background and skills for successful careers in a wide variety of engineering industries that include mining, aerospace, automotive, electronic, biomedical, and many more; or for pursuit of graduate education in materials research and technology development and related fields.

The Metallurgical & Materials Engineering program instills fundamental knowledge pertaining to materials processes including extraction and refining of materials, alloy development, casting, mechanical working, joining and forming, high-temperature reactions, and of engineered materials. The relationship of materials' properties and performance with the microchemistries, microstructures, and controlled defect structures or their elimination is emphasized for all types of applications.

The Ceramic Engineering program provides students valuable knowledge focused on ceramic materials on particle processing, sintering, thermal stability and behavior, glass science, and mechanical strength. The expertise is relevant to technical applications such as semiconductors, biomaterials, optics, energy storage and conversion, and tribological needs as well as traditional applications such as refractories, whitewares, and cements.

Both programs emphasize hands-on experimental work in addition to classroom learning to provide a well-integrated undergraduate education. Engineers from these programs will acquire knowledge in materials’ structure, properties, processing, and performance which can be applied to their desired area of focus.

Program Educational Objectives

The programs have shared department educational objectives such that students graduating:

1. Obtain a range of positions in industry or government facilities or pursue graduate education in engineering, science, or other fields.
2. Demonstrate advancement in their chosen careers.
3. Engage in appropriate professional societies and continuing education activities.

Student Learning Outcomes

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Curriculum

The Metallurgical and Materials Engineering (MME) curriculum is organized to educate students in the fundamentals of materials (MME Basics) and their applications (MME Applications).

A. MME Basics: The basic curriculum in the Metallurgical and Materials Engineering program will provide a background in the following topic areas:

1. Crystal Structures and Structural Analysis: crystal systems; symmetry elements and Miller indices; atomic bonding; metallic, ceramic and polymeric structures; x-ray and electron diffraction; stereographic projection and crystal orientation; long range order; defects in materials.
2. Thermodynamics of Materials: heat and mass balances; thermodynamic laws; chemical potential and chemical equilibrium; solution thermodynamics and solution models; partial molar and excess quantities; solid state thermodynamics; thermodynamics of surfaces; electrochemistry.
3. Transport Phenomena and Kinetics: Heat, mass and momentum transport; transport properties of fluids; diffusion mechanisms; reaction kinetics; nucleation and growth kinetics.
4. Phase Equilibria: phase rule; binary and ternary systems; microstructural evolution; defects in crystals; surface phenomena; phase transformations: eutectic, eutectoid, martensitic, nucleation and growth, recovery; microstructural evolution; strengthening mechanisms; quantitative stereology; heat treatment.
5. Properties of Materials: mechanical properties; chemical properties (oxidation and corrosion); electrical, magnetic and optical properties: failure analysis.

B. MME Applications: The course content in the Metallurgical and Materials Engineering program emphasizes the following applications:

1. Materials Processing: particulate processing; thermo- and electro-chemical materials processing; hydrometallurgical processing; synthesis of materials; deformation processing; solidification and casting; welding and joining.
2. Design and Application of Materials: materials selection; ferrous and nonferrous metals; ceramics; polymers; composites; electronic materials.
3. Statistical Process Control and Design of Experiments: statistical process control; process capability analysis; design of experiments.

C. MME Curriculum Requirements: The Metallurgical and Materials Engineering course sequence is designed to fulfill the program goals and to satisfy the curriculum requirements. The time sequence of courses organized by degree program, year, and semester is listed below.

Degree Requirements (Bachelor of Science in Metallurgical and Materials Engineering)

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
HASS100	NATURE AND HUMAN VALUES (PAGN Elective::PHYSICAL ACTIVITY COURSE)			3.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
S&W	Success and Wellness			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CHGN125	MOLECULAR ENGINEERING & MATERIALS CHEMISTRY or 122			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
MTGN272	MME FIELD SESSION			3.0
				3.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
MTGN202	ENGINEERED MATERIALS			3.0

		lec	lab	sem.hrs
MTGN251	METALLURGICAL AND MATERIALS THERMODYNAMICS			3.0
HASS200	GLOBAL STUDIES			3.0
				17.0

Spring		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
CEEN241	STATICS			3.0
MTGN211	STRUCTURE OF MATERIALS			3.0
MTGN281	INTRODUCTION TO PHASE EQUILIBRIA IN MATERIALS SYSTEMS			2.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
				14.0

Junior

Fall		lec	lab	sem.hrs
CEEN311	MECHANICS OF MATERIALS			3.0
MTGN352	METALLURGICAL AND MATERIALS KINETICS			3.0
MTGN350	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS			3.0
MTGN310	POWDER PROCESSING AND FORMING			2.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
MTGN310L	POWDER PROCESSING AND FORMING LABORATORY			1.0
				15.0

Spring		lec	lab	sem.hrs
MTGN334	CHEMICAL PROCESSING OF MATERIALS			3.0
MTGN334L	CHEMICAL PROCESSING OF MATERIALS LABORATORY			1.0
MTGN348	MICROSTRUCTURAL DEVELOPMENT			3.0
MTGN348L	MICROSTRUCTURAL DEVELOPMENT LABORATORY			1.0
FREE	Free Elective			3.0
MTGN315	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS			3.0
				14.0

Senior

Fall		lec	lab	sem.hrs
MTGN445	MECHANICAL PROPERTIES OF MATERIALS			3.0
MTGN445L	MECHANICAL PROPERTIES OF MATERIALS LABORATORY			1.0
MTGN	MTGN Elective			3.0
MTGN461	TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
MTGN467	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION			2.0
				15.0

Spring		lec	lab	sem.hrs
MTGN	MTGN Elective			3.0
MTGN	MTGN Elective			3.0
MTGN	MTGN Elective			3.0
FREE	Free Elective			3.0
MTGN468	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION			2.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
				17.0

Total Semester Hrs: 127.0

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- MTGN100 through MTGN599 inclusive

Five-Year Combined Metallurgical and Materials Engineering Baccalaureate and Master of Engineering in Metallurgical and Materials Engineering with an Electronic-Materials Emphasis.*

The departments of Metallurgical and Materials Engineering and Physics collaborate to offer a five-year program designed to meet the needs of the electronics and similar high-tech industries. Students who satisfy the requirements of the program obtain an undergraduate degree in Engineering Physics, Metallurgical and Materials Engineering, or Ceramic Engineering in four years and a Master of Engineering degree in Metallurgical and Materials Engineering at the end of the fifth year.

The program is designed to provide a strong background in science fundamentals as well as specialized training in the materials-science and processing needs of these industries. Thus, the educational objective of the program is to provide students with the specific educational requirements to begin a career in microelectronics and, at the same time, a broad and flexible background necessary to remain competitive in this exciting and rapidly-changing industry. The undergraduate electives which satisfy the requirements of the program and an overall curriculum need to be discussed with the student's advisor and approved by the Physics or Metallurgical and Materials Engineering departments. A program mentor in each department can also provide counseling on the program.

Application for admission to this program should be made during the first semester of the sophomore year (in special cases, later entry may be approved upon review by one of the program mentors). Undergraduate students admitted to the program must maintain a 3.0 grade-point average or better. The graduate segment of the program requires a case study report, submitted to the student's graduate advisor. Additional details on the Master of Engineering can be found in the Graduate Degree and Requirements section of the graduate bulletin. The case study is started during the student's senior design project and completed during the year of graduate study. A student admitted to the program is expected to select a graduate advisor in advance of the graduate-studies final year and prior to the start of their senior year. The case-study topic is then identified and selected in consultation with the graduate advisor. A formal application during the senior year for admission to the graduate program in Metallurgical and Materials Engineering must be submitted to the Graduate School. Students who have maintained all the standards of the program requirements leading up to this step can expect to be admitted.

Program Requirements (Bachelor of Science in Ceramic Engineering)

The Ceramic Engineering (CerE) curriculum is organized to educate students in the fundamentals of inorganic materials with a particular focus on ceramics — materials dominated by ionic and/or covalent bonding — and their applications.

A. CerE Basics: The Ceramic Engineering curriculum provides a background in:

1. Atomic Structures and Structural Analysis: crystal systems; symmetry elements and Miller indices; atomic bonding; crystalline and amorphous structures; x-ray and electron diffraction; short- and long-range order; atomic scale defects in materials.
2. Thermodynamics of Materials: heat and mass balances; thermodynamic laws; chemical potential and chemical equilibrium; solution thermodynamics & solution models; partial molar and excess quantities; solid state thermodynamics; thermodynamics of surfaces.
3. Phase Equilibria: phase rule; binary and ternary systems; defects in crystals; surface phenomena; phase transformations: eutectic, eutectoid, martensitic, nucleation and growth, recovery; microstructural evolution; heat treatment.
4. Kinetics and Thermal Phenomena: Heat and mass transport with a focus on the solid state; diffusion mechanisms; reaction kinetics; nucleation and growth kinetics; quenching, tempering, and annealing of glasses and other non-equilibrium materials.
5. Powder Processing: measurement, handling and use of powders; rheology; surface chemistry and colloidal stability; forming (e.g., casting, pressing, extrusion and related processes); calcination; mixing and milling; sintering and microstructural control
6. Statistical Process Control and Design of Experiments: statistical process control; process capability analysis; design of experiments.
7. Properties of Materials: mechanical, thermal, electrical, magnetic, and optical properties; integration and applications of enabling properties.
8. Design, Integration, and Application of Materials: materials selection and compatibility; integration, fabrication, and processing of composites and other multi-material components and devices (including thin film deposition, infiltration, and other approaches)

B. CerE Curriculum Requirements:#TheCeramic Engineering course sequence is designed to fulfill the program goals and to satisfy the curriculum requirements. A recommended sequence of courses organized by year and semester is listed below.

Degree Requirements (Bachelor of Science in Ceramic Engineering)

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
S&W	Success and Wellness			1.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CHGN125	MOLECULAR ENGINEERING & MATERIALS CHEMISTRY or 122			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
MTGN272	MME FIELD SESSION			3.0
				3.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
MTGN202	ENGINEERED MATERIALS			3.0
MTGN251	METALLURGICAL AND MATERIALS THERMODYNAMICS			3.0

HASS200	GLOBAL STUDIES			3.0
				17.0

Spring		**lec**	**lab**	**sem.hrs**
MATH225	DIFFERENTIAL EQUATIONS			3.0
CEEN241	STATICS			3.0
MTGN211	STRUCTURE OF MATERIALS			3.0
MTGN281	INTRODUCTION TO PHASE EQUILIBRIA IN MATERIALS SYSTEMS			2.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
				14.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
CEEN311	MECHANICS OF MATERIALS			3.0
MTGN352	METALLURGICAL AND MATERIALS KINETICS			3.0
MTGN310	POWDER PROCESSING AND FORMING			2.0
MTGN310L	POWDER PROCESSING AND FORMING LABORATORY			1.0
MTGN350	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS			3.0
ELECTIVE	Culture and Society (CAS) Mid-Level Restricted Elective			3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
MTGN319	INTRODUCTION TO GLASS SCIENCE AND TECHNOLOGY			3.0
MTGN319L	INTRODUCTION TO GLASS SCIENCE AND TECHNOLOGY LABORATORY			1.0
MTGN345	SINTERING OF CERAMICS			3.0
MTGN345L	SINTERING OF CERAMICS LABORATORY			1.0
MTGN315	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS			3.0
FREE	Free Elective			3.0
				14.0

Senior

Fall		**lec**	**lab**	**sem.hrs**
MTGN410	THERMAL PROPERTIES OF CERAMICS			3.0
MTGN467	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION			2.0
MTGN	MTGN Elective			3.0
MTGN	MTGN Elective			3.0
ELECTIVE	Culture and Society (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective			3.0
				17.0

Spring		**lec**	**lab**	**sem.hrs**
MTGN468	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION			2.0
MTGN	MTGN Elective			3.0
MTGN	MTGN Elective			3.0
ELECTIVE	Culture and Society (CAS) Mid-Level Restricted Elective			3.0
MTGN465	MECHANICAL PROPERTIES OF CERAMICS			3.0
MTGN465L	MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES LABORATORY			1.0
				15.0

Total Semester Hrs: 127.0

Major GPA

The following list details the courses that are included in the GPA for this degree:

- MTGN100 through MTGN599 inclusive

Five-Year Combined Metallurgical and Materials Engineering Baccalaureate and Master of Engineering in Metallurgical and Materials Engineering with an Electronic-Materials Emphasis.*

The Departments of Metallurgical and Materials Engineering and Physics collaborate to offer a five-year program designed to meet the needs of the electronics and similar high-tech industries. Students who satisfy the requirements of the program obtain an undergraduate degree in Engineering Physics, Metallurgical and Materials Engineering, or Ceramic Engineering in four years and a Master of Engineering degree in Metallurgical and Materials Engineering at the end of the fifth year. The program is designed to provide a strong background in science fundamentals as well as specialized training in the materials-science and processing needs of these industries. Thus, the educational objective of the program is to provide students with the specific educational requirements to begin a career in microelectronics and, at the same time, a broad and flexible background necessary to remain competitive in this exciting and rapidly-changing industry. The undergraduate electives which satisfy the requirements of the program and an overall curriculum need to be discussed with the student's advisor and approved by the Physics or Metallurgical and Materials Engineering departments. A program mentor in each department can also provide counseling on the program.

Application for admission to this program should be made during the first semester of the sophomore year (in special cases, later entry may be approved upon review by one of the program mentors). Undergraduate students admitted to the program must maintain a 3.0 grade-point average or better. The graduate segment of the program requires a case study report submitted to the student's graduate advisor. Additional details on the Master of Engineering can be found in the Graduate Degree and Requirements section of the graduate bulletin. The case study is started during the student's senior design project and completed during the year of graduate study. A student admitted to the program is expected to select a graduate advisor in advance of the graduate studies final year and prior to the start of their senior year. The case-study topic is then identified and selected in consultation with the graduate advisor. A formal application during the senior year for admission to the graduate program in Metallurgical and Materials Engineering must be submitted to the Graduate School. Students who have maintained all the standards of the program requirements leading up to this step can expect to be admitted.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Minor in Metallurgical and Materials Engineering

A minor program in metallurgical and materials engineering consists of a minimum of 18 credits of a logical sequence of courses. Students majoring in metallurgical and material engineering are not eligible to earn a minor in the department.

A minor program declaration (available in the Registrar's Office) must be submitted for approval prior to the student's completion of half of the credits proposed to constitute the program. Approvals are required from the department head of metallurgical and materials engineering, the student's advisor, and the department head or division director in the department or division in which the student is enrolled.

Recommended Courses: The following courses are recommended for students seeking to earn a minor in metallurgical and materials engineering:

MTGN202	ENGINEERED MATERIALS	3.0
MTGN211	STRUCTURE OF MATERIALS	3.0
MTGN348	MICROSTRUCTURAL DEVELOPMENT	3.0
MTGN348L	MICROSTRUCTURAL DEVELOPMENT LABORATORY	1.0
MTGN445	MECHANICAL PROPERTIES OF MATERIALS	3.0
MTGN445L	MECHANICAL PROPERTIES OF MATERIALS LABORATORY	1.0
At least 4 credits of 300- or 400- level courses in metallurgical and materials engineering		4.0
Total Semester Hrs		**18.0**

Other sequences are permissible to suit the special interests of individual students. These other sequences need to be discussed and approved by the department head in metallurgical and materials engineering.

Courses

MTGN198. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 1-3 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN199. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN202. ENGINEERED MATERIALS. 3.0 Semester Hrs.
Equivalent with SYGN202,
Introduction to the Metallurgical and Materials Engineering paradigm: processing, structure, and properties. The course will relate technologically significant processing procedures to resultant structures. The material structure will be examined to determine its effect upon material properties. Students will study materials engineering methodologies and learn terminology. 3 hours lecture; 3 semester hours. Prerequisite: CHGN121, MATH112, and PHGN100.
Course Learning Outcomes

- No change

MTGN211. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.
Principles of atomic bonding, crystallography, and amorphous structures. ii) Symmetry relationships to material properties. iii) Atomic structure determination through diffraction techniques. 3 hours lecture; 3 semester hours. Prerequisite: MTGN202. Co-requisite: PHGN200.
Course Learning Outcomes

- ABET 1, 5

MTGN219. ART AND SCIENCE OF GLASSBLOWING. 2.0 Semester Hrs.
Explore the science of glass by learning artistic glassblowing. Lectures will cover basic glass network structure, melt processing and viscosity, forming and cold working, as well as optical and mechanical properties. Over the course of the semester, laboratory exercises will train students in basic glassblowing and safe use of a hot glass shop. Students who pass the course with a B or better will be certified to use the Hill Hall hot glass shop during open shop hours. Due to the limited capacity of this course, registration opportunities are determined each semester by a random lottery. Details are announced via the Daily Blast a couple of weeks prior to registration begins. This course is not counted towards MME major completion as an MTGN elective.
Course Learning Outcomes

- ABET #4

MTGN251. METALLURGICAL AND MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.
Applications of thermodynamics in extractive and physical metallurgy and materials science. Thermodynamics of solutions including solution models and thermodynamic properties of alloys and slags. Reaction equilibria with examples in alloy systems and slags. Phase stability analysis. Thermodynamic properties of binary alloys in the solid state, defect equilibrium, and interactions. 3 hours lecture; 3 semester hours. Prerequisite: MATH112, CHGN122 or CHGN125, and PHGN100.
Course Learning Outcomes

- ABET1

MTGN272. MME FIELD SESSION. 3.0 Semester Hrs.
Introduction to the field of Metallurgical and Materials Engineering. Overview of opportunities, expectations, and practices within the MME department and the broader materials community. Introduction to bonding, crystal and grain structure, application space, and Structure-Property-Processing relationships. Laboratory projects and plant visits. Prerequisites: MATH112, PHGN100. 9 hours lab; 3 semester hours.
Course Learning Outcomes

- No change

MTGN281. INTRODUCTION TO PHASE EQUILIBRIA IN MATERIALS SYSTEMS. 2.0 Semester Hrs.
Review of the concepts of chemical equilibrium and derivation of the Gibbs phase rule. Use of thermodynamic principles for constructing and interpreting one, two and three component phase equilibrium diagrams. Application to alloy and ceramic materials systems. Emphasis on the evolution of phases and their amounts and the resulting microstructural development. Prerequisite: MTGN202, MTGN251.
Course Learning Outcomes

- ABET 1

MTGN298. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN298. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN299. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN300. FOUNDRY METALLURGY. 2.0 Semester Hrs.
Design and metallurgical aspects of casting, patterns, molding materials and processes, solidification processes, risers and gating concepts, casting defects and inspection, melting practice, cast alloy selection. 2 hours lecture; 2 semester hours. Co-requisite: MTGN300L.
Course Learning Outcomes

- ABET 3

MTGN300L. FOUNDRY METALLURGY LABORATORY. 1.0 Semester Hr.
Equivalent with MTGN302,
Experiments in the foundry designed to supplement the lectures of MTGN300. 3 hours lab; 1 semester hour. Co-requisite: MTGN300.
Course Learning Outcomes

- ABET 3

MTGN310. POWDER PROCESSING AND FORMING. 2.0 Semester Hrs.
Fabrication of components from powder-based feedstocks is central to both ceramic and metallurgical engineering, and the concepts of powder processing apply to industries as diverse as mining, food products, paints, and many more. This course covers the handling, measurement, and application of powdered feedstocks to the formation of green bodies (i.e., powder compacts) using both wet and dry methods. Particular attention is paid to the importance of powder characteristics, green density, impurities and other defects in these initial stages to the final density, microstructure and overall properties of the subsequent part, whether the parts are sintered or consolidated in another way such as laser powder bed fusion (LPBF). Prerequisite: MTGN202, MTGN251. Co-requisite: MTGN310L.
Course Learning Outcomes

- 1. exhibit basic competence in wet and dry handling of fine powders
- 2. apply both optical and mechanical approaches to the measurement of particle size and distribution and apply both mechanical and fluid-based approaches to particle size sorting
- 3. exhibit basic competence in wet processing of powders and control of rheology through colloidal dispersion and stabilization techniques
- 4. demonstrate powder based forming of a macroscopic component

MTGN310L. POWDER PROCESSING AND FORMING LABORATORY. 1.0 Semester Hr.
Fabrication of components from powder-based feedstocks is central to both ceramic and metallurgical engineering, and the concepts of powder processing apply to industries as diverse as mining, food products, paints, and many more. This course covers the handling, measurement, and application of powdered feedstocks to the formation of green bodies (i.e., powder compacts) using both wet and dry methods. Particular attention is paid to the importance of powder characteristics, green density, impurities and other defects in these initial stages to the final density, microstructure and overall properties of the subsequent part, whether the parts are sintered or consolidated in another way such as laser powder bed fusion (LPBF). Prerequisite: MTGN202, MTGN251. Co-requisite: MTGN310.
Course Learning Outcomes

- 1. exhibit basic competence in wet and dry handling of fine powders
- 2. apply both optical and mechanical approaches to the measurement of particle size and distribution and apply both mechanical and fluid-based approaches to particle size sorting
- 3. exhibit basic competence in wet processing of powders and control of rheology through colloidal dispersion and stabilization techniques
- 4. demonstrate powder based forming of a macroscopic component

MTGN314. PROPERTIES AND PROCESSING OF CERAMICS. 2.0 Semester Hrs.
Application of engineering principles and fundamental structure-processing-property relationship to inorganic non-metallic materials. Emergence of macroscopic characteristics and functional properties from bonding, structure, symmetry, and defects. Applications of basic thermodynamic and kinetic principles to powder-based processing. 2 hours lecture; 2 semester hours. Co-requisite: MTGN314L, MTGN202, and MTGN251.
Course Learning Outcomes

- ABET 1, 6

MTGN314L. PROPERTIES AND PROCESSING OF CERAMICS LABORATORY. 1.0 Semester Hr.
Laboratory for MTGN314. 3 hours lab; 1 semester hour. Co-requisite: MTGN314.
Course Learning Outcomes

- ABET 3

MTGN315. ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS. 3.0 Semester Hrs.
Survey of aspects of modern physics needed to understand selected properties of materials including conductivity (electrical, thermal, etc.), electronic states of materials, density of states, the nature of bands and bonding and how they arise, total and cohesive energy of solids based on filling of states, the nature of metals, semiconductors, and dielectrics and how these arise from electronic states, and the application of these concepts to understand dielectrics, magnetism, and semiconductor devices. Prerequisite: PHGN200, MATH225, MTGN211.
Course Learning Outcomes

- ABET 1, 2, 5

MTGN319. INTRODUCTION TO GLASS SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Introduction to the principles of glass science and engineering and non-crystalline materials. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisite: MTGN202. Co-requisite: MTGN319L.
Course Learning Outcomes

- 1. Understand atomic origins and structure of amorphous solids
- 2. Understand the principles of glass formation from melts
- 3. Understand and engineer the mechanical, optical, transport, and electrical properties of glasses
- 4. Engineer glass materials for biological, optical, and thermal applications

MTGN319L. INTRODUCTION TO GLASS SCIENCE AND TECHNOLOGY LABORATORY. 1.0 Semester Hr.
Introduction to the principles of glass science and engineering and non-crystalline materials. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisite: MTGN202. Co-requisite: MTGN319.
Course Learning Outcomes

- 1. Understand atomic origins and structure of amorphous solids
- 2. Understand the principles of glass formation from melts
- 3. Understand and engineer the mechanical, optical, transport, and electrical properties of glasses
- 4. Engineer glass materials for biological, optical, and thermal applications

MTGN333. INTRODUCTION TO BLADESMITHING. 3.0 Semester Hrs.
An introduction to the metallurgy and art of bladesmithing. The course covers ferrous metallurgy with a focus on tools steels used for creating edged tools. Students will learn and execute techniques for alloy selection, shaping, profiling, beveling, heat treating, and sharpening knives. Students will complete at least two knives, one specified by the instructor, and one of the students own design. Co-requisite: MTGN348 or instructor consent.
Course Learning Outcomes

- ABET a, b, c

MTGN334. CHEMICAL PROCESSING OF MATERIALS. 3.0 Semester Hrs.
Development and application of fundamental principles related to the processing of metals and materials by thermochemical, aqueous, and fused salt electrochemical/chemical routes. The course material is presented within the framework of a formalism that examines the physical chemistry, thermodynamics, reaction mechanisms and kinetics inherent to a wide selection of chemical processing systems. The general formalism provides for a transferable knowledge-base to other systems not specifically covered in the course. Prerequisite: MTGN272 and MTGN251. Co-requisite: MTGN334L.
Course Learning Outcomes

- no change

MTGN334L. CHEMICAL PROCESSING OF MATERIALS LABORATORY. 1.0 Semester Hr.
Experiments in chemical processing of materials to supplement the lectures of MTGN334. 3 hours lab; 1 semester hour. Co-requisite: MTGN334.
Course Learning Outcomes

- ABET 1, 2

MTGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. 1 to 3 semester hours. Cooperative education credit does not count toward graduation except under special conditions. Repeatable.
Course Learning Outcomes

- depends

MTGN345. SINTERING OF CERAMICS. 3.0 Semester Hrs.
This course covers the fundamentals and applications of sintering based processes in ceramic engineering. It includes solid-state, liquid phase, reactive and vapor phase sintering and covers densifying and non-densifying mechanisms as well as microstructure development for bulk, coatings, and additively manufactured parts. The course covers technologies used in the processing of ceramics. Prerequisite: MTGN310, MTGN352, MTGN281. Co-requisite: MTGN345L.
Course Learning Outcomes

- 1. Exhibit a basic understanding of sintering mechanisms in ceramics
- 2. Engineer microstructure development of powder-based specimens from green body to dense polycrystalline ceramics
- 3. Design a thermal profile to produce a desired microstructure for a given material for different processing techniques
- 4. Characterize abnormal grain growth, solute drag, pore drag, and Zener pinning

MTGN345L. SINTERING OF CERAMICS LABORATORY. 1.0 Semester Hr.
This is the laboratory course for MTGN345. This course covers the fundamentals and applications of sintering based processes in ceramic engineering. It includes solid-state, liquid phase, reactive and vapor phase sintering and covers densifying and non-densifying mechanisms as well as microstructure development for bulk, coatings, and additively

manufactured parts. The course covers technologies used in the processing of ceramics. Prerequisite: MTGN310, MTGN352, MTGN281. Co-requisite: MTGN345.
Course Learning Outcomes

- 1. exhibit a basic understanding of sintering mechanisms in ceramics
- 2. engineer microstructure development of powder-based specimens from green body to dense polycrystalline ceramics
- 3. design a thermal profile to produce a desired microstructure for a given material for different processing techniques
- 4. to characterize abnormal grain growth, solute drag, pore drag, and Zener pinning

MTGN348. MICROSTRUCTURAL DEVELOPMENT. 3.0 Semester Hrs.
An introduction to the relationships between microstructure and properties of materials, with emphasis on metallic and ceramic systems; Fundamentals of imperfections in crystalline materials on material behavior; recrystallization and grain growth; strengthening mechanisms: microstructural refinement, solid solution strengthening, precipitation strengthening, cold work; and phase transformations. Prerequisite: MTGN211, MTGN251. Co-requisite: MTGN281, MTGN348L.
Course Learning Outcomes

- ABET 1, 3

MTGN348L. MICROSTRUCTURAL DEVELOPMENT LABORATORY. 1.0 Semester Hr.
Experiments in microstructural development of materials to supplement the lectures of MTGN348. 3 hours lab; 1 semester hour. Co-requisite: MTGN348.
Course Learning Outcomes

- ABET 1, 3

MTGN350. STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS. 3.0 Semester Hrs.
Introduction to statistical process control, process capability analysis and experimental design techniques. Statistical process control theory and techniques developed and applied to control charts for variables and attributes involved in process control and evaluation. Process capability concepts developed and applied to the evaluation of manufacturing processes. Theory of designed experiments developed and applied to full factorial experiments, fractional factorial experiments, and multilevel experiments. Analysis of designed experiments by graphical and statistical techniques. Introduction to computer software for statistical process control and for the design and analysis of experiments.
Course Learning Outcomes

- ABET 1, 3

MTGN352. METALLURGICAL AND MATERIALS KINETICS. 3.0 Semester Hrs.
Introduction to reaction kinetics: chemical kinetics, atomic and molecular diffusion, surface thermodynamics and kinetics of interfaces and nucleation-and-growth. Applications to materials processing and performance aspects associated with gas/solid reactions, precipitation and dissolution behavior, oxidation and corrosion, purification of semiconductors, carburizing of steel, formation of p-n junctions and other important materials systems. Prerequisite: MTGN272. Co-requisite: MTGN251.
Course Learning Outcomes

- ABET 1, 2

MTGN398. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN399. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN403. SENIOR THESIS. 3.0 Semester Hrs.
(I, II,S) Two-semester individual research under the direction of members of the MME faculty. Work may include library and laboratory research on topics of relevance. Oral presentation will be given at the end of the second semester and written thesis submitted to committee of evaluation. 3 hours research; 3 semester hours.
Course Learning Outcomes

- depends

MTGN410. THERMAL PROPERTIES OF CERAMICS. 3.0 Semester Hrs.
This course covers the fundamentals and applications of ceramic materials? responses to thermal energy. Thermal responses are fundamentally borne from atomic scale processes which will be covered in detail. Particular attention is paid to thermal conduction, melting, thermally induced strain, thermomechanical stresses, and engineering microstructures to obtain specific thermal performances. Prerequisite: MTGN315, MTGN310.
Course Learning Outcomes

- 1. Understand atomic and thermodynamic material responses to thermal energy
- 2. Understand and engineer thermal conduction processes in materials and devices
- 3. Engineer thermomechanical responses to thermal energy including expansion and thermal shock
- 4. Engineer ceramic materials for thermal insulation applications

MTGN414. ADVANCED PROCESSING AND SINTERING OF CERAMICS. 3.0 Semester Hrs.
Principles of ceramics processing and the relationship between processing and microstructure, with a focus on advanced microstructural control using thermal and athermal energy input in single and multiphase systems. Principles will be illustrated using case studies on specific ceramic materials. A project to design a ceramic fabrication process is required. Prerequisite: MTGN314. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- ABET 1, 2, 3

MTGN419. NON-CRYSTALLINE MATERIALS. 3.0 Semester Hrs.
Introduction to the principles of glass science and engineering and non-crystalline materials in general. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisite: MTGN211 and MTGN314.

Course Learning Outcomes

- ABET 1, 2

MTGN429. METALLURGICAL ENVIRONMENT. 3.0 Semester Hrs.
(I) Examination of the interface between metallurgical process engineering and environmental engineering. Wastes, effluents and their point sources in metallurgical processes such as mineral concentration, value extraction and process metallurgy are studied in context. Fundamentals of metallurgical unit operations and unit processes with those applicable to waste and effluent control, disposal and materials recycling are covered. Engineering design and engineering cost components are also included for selected examples. Fundamentals and applications receive equal coverage. Prerequisites: MTGN334. 3 hours lecture; 3 semester hours.

MTGN430. PHYSICAL CHEMISTRY OF IRON AND STEELMAKING. 3.0 Semester Hrs.
Physical chemistry principles of blast furnace and direct reduction production of iron and refining of iron to steel. Discussion of raw materials, productivity, impurity removal, deoxidation, alloy additions, and ladle metallurgy. Prerequisite: MTGN334, MTGN251.
Course Learning Outcomes

- ABET 1, 2

MTGN431. HYDRO- AND ELECTRO-METALLURGY. 3.0 Semester Hrs.
Physicochemical principles associated with the extraction and refining of metals by hydro- and electrometallurgical techniques. Discussion of unit processes in hydrometallurgy, electrowinning, and electrorefining. Analysis of integrated flowsheets for the recovery of nonferrous metals. Offered every other year. 3 hours lecture; 3 semester hours. Prerequisite: MTGN334, MTGN352, and MTGN251. Co-requisite: MTGN461.
Course Learning Outcomes

- ABET 1

MTGN432. PYROMETALLURGY. 3.0 Semester Hrs.
Extraction and refining of metals including emerging practices. Modifications driven by environmental regulations and by energy minimization. Analysis and design of processes and the impact of economic constraints. Prerequisite: MTGN334. 3 hours lecture; 3 semester hours.

MTGN442. ENGINEERING ALLOYS. 3.0 Semester Hrs.
This course is intended to be an important component of the physical metallurgy sequence, to reinforce and integrate principles from earlier courses, and enhance the breadth and depth of understanding of concepts in a wide variety of alloy systems. Metallic systems considered include iron and steels, copper, aluminum, titanium, superalloys, etc. Phase stability, microstructural evolution and structure/property relationships are emphasized. Offered every year. Prerequisite: MTGN348.
Course Learning Outcomes

- ABET 2, 6

MTGN445. MECHANICAL PROPERTIES OF MATERIALS. 3.0 Semester Hrs.
Mechanical properties and relationships. Plastic deformation of crystalline materials. Relationships of microstructures to mechanical strength. Fracture, creep, and fatigue. 3 hours lecture, 3 semester hours. Prerequisite: MTGN348 and CEEN241 and CEEN311. Co-requisite: MTGN445L.
Course Learning Outcomes

- ABET 4, 5,7

MTGN445L. MECHANICAL PROPERTIES OF MATERIALS LABORATORY. 1.0 Semester Hr.
Laboratory sessions devoted to advanced mechanical-testing techniques to illustrate the application of the fundamentals presented in the lectures of MTGN445. Corequisite: MTGN445. 3 hours lab; 1 semester hour.
Course Learning Outcomes

- ABET 4,5 7

MTGN451. CORROSION ENGINEERING. 3.0 Semester Hrs.
Principles of electrochemistry. Corrosion mechanisms. Methods of corrosion control including cathodic and anodic protection and coatings. Examples of corrosion problems and solutions from various industries. Prerequisite: MTGN251.
Course Learning Outcomes

- No change

MTGN456. ELECTRON MICROSCOPY. 2.0 Semester Hrs.
Introduction to electron optics and the design and application of transmission and scanning electron microscopes. Interpretation of images produced by various contrast mechanisms. Electron diffraction analysis and the indexing of electron diffraction patterns. 2 hours lecture; 2 semester hours. Prerequisite: MTGN211. Co-requisite: MTGN456L.
Course Learning Outcomes

- ABET 1, 3

MTGN456L. ELECTRON MICROSCOPY LABORATORY. 1.0 Semester Hr.
Equivalent with MTGN458,
Laboratory exercises to illustrate specimen preparation techniques, microscope operation, and the interpretation of images produced from a variety of specimens, and to supplement the lectures in MTGN456. 3 hours lab; 1 semester hour. Co-requisite: MTGN456.
Course Learning Outcomes

- ABET 1, 3

MTGN457. SOLIDIFICATION. 3.0 Semester Hrs.
This course is intended to provide students with a working understanding of solidification processing of metals relevant to crystal growth, casting, welding, and additive manufacturing. Topics in the course are: 1) thermodynamics, 2) nucleation, 3) heat transfer, 4) interface stability and solidification morphology, 5) dendritic growth, 6) microsegregation, and 7) columnar vs equiaxed dendritic growth. Prerequisite: MTGN348.
Course Learning Outcomes

MTGN461. TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS. 3.0 Semester Hrs.
Introduction to the conserved-quantities: momentum, heat, and mass transfer, and application of chemical kinetics to elementary reactor-design. Examples from materials processing and process metallurgy. Molecular transport properties: viscosity, thermal conductivity, and mass diffusivity of materials encountered during processing operations. Uni-directional transport: problem formulation based on the required balance of the conserved- quantity applied to a control-volume. Prediction of velocity, temperature and concentration profiles. Equations of

change: continuity, motion, and energy. Transport with two independent variables (unsteady-state behavior). Interphase transport: dimensionless correlations friction factor, heat, and mass transfer coefficients. Elementary concepts of radiation heat-transfer. Flow behavior in packed beds. Design equations for: continuous- flow/batch reactors with uniform dispersion and plug flow reactors. Digital computer methods for the design of metallurgical systems. Prerequisite: MATH225, MTGN334, and MTGN352. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- ABET 1,3

MTGN462. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.
This course will examine, using case studies, how industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisites: CEEN301, CEEN302, and CHGN403. 3 hours lecture; 3 semester hours.

MTGN464. FORGING AND FORMING. 2.0 Semester Hrs.
Introduction to plasticity, survey and analysis of working operations including forging, extrusion, rolling, wire drawing and sheet-metal forming. Metallurgical structure evolution during working. Prerequisite: MTGN281 or CEEN311, MTGN348. Co-requisite: MTGN464L.
Course Learning Outcomes

- ABET 1

MTGN464L. FORGING AND FORMING LABORATORY. 1.0 Semester Hr.
Experiments in forging and forming to supplement the lectures of MTGN464. 3 hours lab; 1 semester hour. Co-requisite: MTGN464.
Course Learning Outcomes

- ABET 1

MTGN465. MECHANICAL PROPERTIES OF CERAMICS. 3.0 Semester Hrs.
Mechanical properties of ceramics and ceramic-based composites; brittle fracture of solids; toughening mechanisms in composites; fatigue, high-temperature mechanical behavior, including fracture and creep deformation. Offered every year. Prerequisite: MTGN310, CEEN241, CEEN311. Co-requisite: MTGN465L.
Course Learning Outcomes

- ABET 1

MTGN465L. MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES LABORATORY. 1.0 Semester Hr.
Mechanical properties of ceramics and ceramic-based composites; brittle fracture of solids; toughening mechanisms in composites; fatigue, high temperature mechanical behavior, including fracture, creep deformation. Prerequisite: MTGN345. Co-requisite: MTGN465.
Course Learning Outcomes

- 1) Reduce, interpret and analyze experimental data from a variety of mechanical property tests.
- 2) Prepare and submit concise and coherent technical laboratory reports.
- 3) apply mechanical property models such as fracture mechanics to ceramic and composite behavior.
- 4) Describe ceramic and composite mechanical properties and behavior in terms of mechanisms.
- 5) Identify and classify different types of ceramic and composite mechanical constitutive responses.

MTGN467. MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION. 2.0 Semester Hrs.
Application of fundamental materials engineering principles to the design of systems, processes, and/or components for extraction, synthesis, operation and/or selection of materials in open-ended projects with realistic constraints. Project topics range from processes used for metallurgical processing and extraction to design and development of emergent materials to process/component analysis and (re)design. Chemical and microstructural characterization and property measurements provide the basis for linking synthesis to application and/or process to product. Selection criteria tied to specific requirements drive design under realistic constraints that include an appropriate mix of technical, economic, safety, and other considerations. Activities are carried out in teams in collaboration with project sponsors/clients. 1 hour lecture, 3 hours lab; 2 semester hours. Prerequisite: MTGN350, MTGN352, and MTGN348 or MTGN345.
Course Learning Outcomes

- ABET 1-7

MTGN468. MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION. 2.0 Semester Hrs.
Application of fundamental materials engineering principles to the design of systems, processes, and/or components for extraction, synthesis, operation and/or selection of materials in open-ended projects with realistic constraints. Project topics range from processes used for metallurgical processing and extraction to design and development of emergent materials to process/component analysis and (re)design. Chemical and microstructural characterization and property measurements provide the basis for linking synthesis to application and/or process to product. Selection criteria tied to specific requirements drive design under realistic constraints that include an appropriate mix of technical, economic, safety, and other considerations. Activities are carried out in teams in collaboration with project sponsors/clients. Prerequisite: MTGN467. 1 hour lecture, 3 hours lab; 2 semester hours.
Course Learning Outcomes

- ABET 1-7

MTGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Fuel cells provide one of the most efficient means for converting the chemical energy stored in a fuel to electrical energy. Fuel cells offer improved energy efficiency and reduced pollution compared to heat engines. While composed of no (or very few) moving parts, a complete fuel cell system amounts to a small chemical plant for the production of power. This course introduces students to the fundamental aspects of fuel cell systems, with emphasis placed on proton exchange membrane (PEM) and solid oxide fuel cells (SOFC). Students will learn the basic principles of electrochemical energy conversion while being exposed to relevant topics in materials science, thermodynamics, and fluid mechanics. Offered every other year. Prerequisite: PHGN200, MATH225, MTGN251 or CHGN209 or CHGN210 or MEGN261.
Course Learning Outcomes

- ABET 1, 2, 6

MTGN472. BIOMATERIALS I. 3.0 Semester Hrs.
This course introduces biomaterials by combining materials engineering principles with understanding of aspects of molecular and cellular biology so that students learn how materials interact with biological systems, particularly for medical use. The course is organized around four main topics: 1) fundamental properties of biomaterials; 2) fundamental concepts in biology relevant to biomaterials; 3) interactions of physiological systems with biomaterials, and 4) processing of biopolymers, bioceramics and glasses, biometals and composites. Key topics covered include processing of materials to achieve specific biological responses, surface energy and surface modification; protein adsorption; cell adhesion, spreading and migration; biomaterials implantation and acute inflammation; blood-materials interactions; biofilms and biomaterials degradation; and clinical applications of biomaterials. Offered every other year. Prerequisite: MTGN202. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- ABET 1, 5, 6

MTGN473. COMPUTATIONAL MATERIALS. 3.0 Semester Hrs.
(II) Computational Materials is a course designed as an introduction to computational approaches used in modern materials science and engineering, and to provide the hands-on experience in using massively parallel supercomputers and executing popular materials software packages. The main goal is to provide exposure to students to the growing and highly interdisciplinary field of computational materials science and engineering, through a combination of lectures, hands-on exercises and a series of specifically designed projects. The course is organized to cover different length scales including: atomistic (electronic structure) calculations, molecular dynamics, and phase equilibria modeling. The emerging trends in data driven materials discovery and design are also covered. Particular emphasis is placed on the validation of computational results and recent trends in integrating theory, computations and experiment. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Module 1: 1. Introduction to computational materials science and engineering
- Module 2: Electronic structure calculations
- Module 3: Molecular dynamics calculations
- Module 4: Materials thermodynamics and phase equilibria modeling

MTGN475. METALLURGY OF WELDING. 2.0 Semester Hrs.
Introduction to welding processes; thermal aspects; selection of filler metals; stresses; stress relief and annealing; pre- and postweld heat treating; weld defects; welding ferrous and nonferrous alloys; weld metal phase transformations; metallurgical evaluation of resulting weld microstructures and properties; and welding tests. Offered every year. Prerequisite: MTGN348. Co-requisite: MTGN475L.
Course Learning Outcomes

- ABET 1, 3, 4

MTGN475L. METALLURGY OF WELDING LABORATORY. 1.0 Semester Hr.
Equivalent with MTGN477,
Experiments designed to supplement the lectures in MTGN475. Offered every year. Co-requisite: MTGN475.
Course Learning Outcomes

- ABET 1,3, 4

MTGN480. ADVANCED WELDING METALLURGY. 3.0 Semester Hrs.
This course will explore microstructural development that occurs during welding. Solidification in the fusion zone as well as solid-state microstructural changes in the heat affected zone will be discussed. We will use the understanding of microstructural changes during welding to interpret cracking mechanisms and unique behaviors of specific alloy systems. The interrelationship between modeling/simulation and experiments will be emphasized. Throughout the course, we will think about how the people to who actually weld (welders) can provide critical insight to solve welding metallurgy problems. Prerequisite: MTGN348. Co-requisite: none.
Course Learning Outcomes

- At the completion of the course, the student will be able to: 1) Describe welding related phenomena with correct terminology 2) Understand how composition affects welding behavior 3) Apply models to predict aspects of microstructure, properties, and performance 4) Evaluate model predictions against experimental results

MTGN497. SUMMER PROGRAMS. 0.0 Semester Hrs.
(S) Summer registration. Repeatable.

MTGN498. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II, S) Independent advanced-work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Selection of problem is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit to a maximum of 6 hours.

Professors

Geoff Brennecka

Kip O. Findley, John Henry Moore Chair

Brian P. Gorman

Michael J. Kaufman, Co-Director of the Center for Advanced Non-Ferrous Structural Alloys (CANFSA)

Jeffrey C. King

Suveen N. Mathaudhu

Emmanuel De Moor

Ryan P. O'Hayre

Ivar E. Reimanis, Department Head, George S. Ansell Distinguished Chair

John G. Speer, Director of the Advanced Steel Processing and Products Research Center (ASPPRC), American Bureau of Shipping Endowed Chair in Metallurgical and Materials Engineering

Associate Professors

Vladan Stevanovic

Zhenzhen Yu, Director of the Center for Welding, Joining and Coatings Research (CWJCR)

Assistant Professors

Lawrence Cho

Xiaolei Guo

Megan Holtz

Jihye Kim

Jonah Klemm-Toole

Eve Mozur

Anna Staerz

Teaching Professors

Gerald Bourne, Associate Department Head, Charles F. Fogarty Limited Professorship

Kimberly Scott

Research Faculty

Corby G. Anderson

Lawrence Cho

Amy Clark

Kester Clarke

Robert Cryderman

Arun Devaraj

David Diercks

Prashun Gorai

Jaeheon Lee

Terry Lowe

Steve Midson

Nelson Delfino De Campos Neto

Michael Sanders

Sridhar Seetharaman

Billy Stanbery

Andriy Zakutayev

Affiliate Faculty

Adam Creuziger

C. Matthew Enloe

Ron Goldfarb

Andrew Kustas

Patricio Mendez

Nathan Orloff

Terry Totemeier

Emeriti Professors

Glen R. Edwards, University Professor Emeritus

John P. Hager, University Professor Emeritus

George Krauss, University Professor Emeritus

Stephen Liu, University Professor Emeritus, Inaugural American Bureau of Shipping Chair Professor

Gerard P. Martins, Professor Emeritus

David K. Matlock, University Professor Emeritus

Brajendra Mishra, University Professor Emeritus

John J. Moore, Professor Emeritus

David L. Olson, University Professor Emeritus

Dennis W. Readey, Universtiy Professor Emeritus

Patrick R. Taylor, Professor Emeritus

Chester J. Van Tyne, Professor Emeritus

Emeriti Associate Professors

Gerald L. DePoorter

Robert H. Frost

Steven W. Thompson

Mining Engineering

Program Description

Mining engineering is a broad profession, which embraces all required activities to facilitate the recovery of valuable metals and minerals from the earth’s crust for the benefit of humanity. It is one of the oldest engineering professions, which continues to grow in importance. Everything in our "built world" requires metals and minerals, or tools and machinery required for construction and manufacturing. An adequate supply of mineral products at competitive prices is the lifeblood of the continuing growth of industrialized nations and the foundation of progress for the developing countries.

The function of the mining engineer is to apply knowledge of pertinent scientific theory, engineering fundamentals, and improved technology to recover natural resources. Mining is a world-wide activity involving the extraction of nonmetallic and metallic ores of all kinds, as well as solid fuel and energy sources such as coal and nuclear materials. In addition to mineral extraction, the skills of mining engineers are also needed in a variety of fields where the earth’s crust is utilized, such as the underground construction industry. The construction industry, with its requirements of developing earth (rock) systems, tunnels and underground chambers, and the hazardous waste disposal industry are examples of such applications. These are expanding needs, with a shortage of competent people; the mining engineer is well qualified to meet these needs.

The importance of environmental and societal impacts is recognized and given significant attention in all aspects of the mining engineering curriculum.

Mines Mining Engineering students study the principles and techniques of mineral exploration, and underground and surface mining operations, as well as, mineral processing technologies. Studies include rock mechanics, rock fragmentation, plant and mine design, mine ventilation, surveying, valuation, industrial hygiene, mineral law, mine safety, computing, mineral processing, solution mining and operations research. Throughout the mining engineering curriculum, a constant effort is made to maintain a balance between theoretical principles and their engineering applications. The mining engineering graduate is qualified for positions in engineering, supervision, and research.

The department recognizes the high expectations that industry has for our graduates as well as the responsibility we have to prepare our students for successful professional careers. To be successful, it is imperative that mining graduates possess an ever-growing set of technical skills, knowledge, and expertise. Beyond the technical aspects of basic sciences, engineering fundamentals, and problem-solving, mining engineering graduates must also acquire a host of other skills which are essential in today's global economy.

These include:

- The ability to work in interdisciplinary teams and communicate effectively to different types of audiences.
- An appreciation of the social, political, and economic realities of different cultures, countries, and indigenous peoples.
- An understanding of the global role mineral extraction and resource development have on local, regional, and international levels.
- The desire for continuing and lifelong education, intellectual and professional development, analysis, and creativity.
- The need to maintain high professional and ethical standards.
- The importance of self-confidence, conviction, and compassion.
- The skills critical to leadership and supervision.

Put simply, our vision for the Mining Engineering Department is to be internationally recognized as the world's premiere center for education and applied research in the diverse fields of mining and underground construction and tunneling. This vision spans across numerous interdisciplinary areas of study. Through collaborations with other Mines departments, academic institutions, government agencies, and industry, we are committed to expanding the international reputation of the Department for excellence in education, research, industry service, and community outreach.

The Mining Engineering Department's program objectives are:

1. Have knowledge of and skills in engineering fundamentals to solve complex and open-ended mining and earth systems-related problems.
2. Demonstrate teamwork and leadership skills relevant to their chosen profession.
3. Several years after leaving Mines, our graduates will achieve professional growth.

The Bachelor of Science in Mining Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission's General Criteria and Program Criteria for Mining Engineering.

Program Educational Objectives (Bachelor of Science in Mining Engineering)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate profile and the ABET accreditation criteria, the educational objectives which the Mining Engineering Department aspires to accomplish can be seen in the attributes of our graduates. The graduate will:

- Obtain professional positions in minerals or related industries, government, or pursue graduate education;
- Demonstrate advancement in their chosen careers through strong technical skills , work on interdisciplinary teams and diverse environments, effective communication, knowledge of current issues, and high standard of ethical conduct;
- Engage in appropriate professional societies and continuing education activities to achieve professional growth

Student Learning Outcomes

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Curriculum

The Mining Engineering curriculum is devised to facilitate the widest employability of CSM graduates. The curriculum is based on scientific engineering and geologic fundamentals and the application of these fundamentals to design and operate mines and to create structures in rock and prepare mine products for the market. To achieve this goal, the curriculum is designed to ensure that the graduates:

- become broad based mining engineers who can tackle the problems of both hard and soft rock mining, regardless of whether the mineral deposit requires surface or underground methods of extraction,
- have an opportunity, through elective courses, to specialize in one or more aspects of the mining engineering profession,
- are interested in an academic or research career, or wish to pursue employment in related fields, have a sufficiently sound scientific and engineering foundation to do so effectively.

This purpose permeates both the lower and upper-division courses. Another important aspect of the curriculum is the development of the students' capabilities to be team members, with the added objective of preparing them for leadership in their professional life. The curriculum focuses on the application of engineering principles to solving problems, in short, engineering design in an earth systems approach.

Degree Requirements (Mining Engineering)

Freshman

Fall		**lec**	**lab**	**sem.hrs**
HASS100	NATURE AND HUMAN VALUES			3.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
S&W	SUCCESS AND WELLNESS			1.0
				17.0

Spring		**lec**	**lab**	**sem.hrs**
PHGN100	PHYSICS I - MECHANICS			4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0

Sophomore

Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
MNGN318	STATICS AND DYNAMICS COMBINED FOR MN			4.0
HASS200	GLOBAL STUDIES			3.0
				15.0

Spring		**lec**	**lab**	**sem.hrs**
MATH225	DIFFERENTIAL EQUATIONS			3.0
CEEN311	MECHANICS OF MATERIALS			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the course, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
MNGN210	INTRODUCTORY MINING			3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				15.0

Summer		**lec**	**lab**	**sem.hrs**
MNGN308	MINE SAFETY			1.0
MNGN203	SOFTWARE FUNDAMENTALS FOR 3D DATA ANALYSIS AND MINE PLANNING			1.0
MNGN205	MINING ENGINEERING FIELD EXPERIENCE(optional)			
				2.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
MNGN310	EARTH MATERIALS			3.0
MNGN309	MINE SAFETY AND OPERATIONS			2.0
MNGN312	SURFACE MINE DESIGN			3.0
MNGN321	INTRODUCTION TO ROCK MECHANICS			3.0
EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER			3.0
FREE	Free Elective			3.0
				17.0

Spring		**lec**	**lab**	**sem.hrs**
MNGN311	MINING GEOLOGY			3.0
MNGN314	UNDERGROUND MINE DESIGN			3.0
MEGN351/ PEGN251	FLUID MECHANICS or PEGN 251			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective			3.0
				15.0

Summer		lec	lab	sem.hrs
MNGN301	MINE SURVEYING			2.0
				2.0

Senior

Fall		lec	lab	sem.hrs
MNGN322	INTRODUCTION TO MINERAL PROCESSING AND LABORATORY			3.0
MNGN414	MINE PLANT DESIGN			3.0
MNGN428	MINING ENGINEERING EVALUATION AND DESIGN REPORT I			1.0
MNGN438	GEOSTATISTICS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective			3.0
				16.0

Spring		lec	lab	sem.hrs
MNGN429	MINING ENGINEERING EVALUATION AND DESIGN REPORT II			2.0
MNGN433	MINE SYSTEMS ANALYSIS I			3.0
MNGN427	MINE VALUATION			2.0
MNGN410	EXCAVATION PROJECT MANAGEMENT			2.0
MNGN425	MINE VENTILATION AND THERMODYNAMICS			4.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
				16.0

Total Semester Hrs: 131.0

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- MNGN100 through MNGN599 inclusive

Minor Programs

The Mining Engineering Department offers three minor programs: the traditional mining engineering program for non-mining majors, underground construction, and tunneling and explosive engineering.

Mining Engineering Minor

The minor program in mining engineering requires students to take:

Required for all students:		3.0
MNGN210	INTRODUCTORY MINING	
Select two of the following:		6.0
MNGN312	SURFACE MINE DESIGN	
MNGN314	UNDERGROUND MINE DESIGN	
MNGN316	COAL MINING METHODS	
Other courses from mining engineering		9.0
Total Semester Hrs		**18.0**

The list of available courses can be found in the mining engineering department office.

Explosive Engineering Minor

Program Advisor: Lee Fronapfel

There are very few academic explosive engineering programs worldwide. Colorado School of Mines is one of a few educational institutions that offers an explosive engineering minor program in the U.S.A. Developed in the Mines tradition of combining academic education with hands-on experience, this minor program will prepare students for new and developing applications involving the use of explosives in the mining and materials engineering, underground construction, oil and gas operations, demolition, homeland security, military, forensic investigations, manufacturing and material synthesis.

With the proper program development of courses and basic knowledge in explosive engineering, students enrolled in this program will discover and gain insight into the exciting industrial applications of explosives, selection of explosives, and the correct and safe use of the energetic materials. With the help of the program advisor, the students will design and select the proper course sequence and complete hands-on research project under the supervision of a faculty advisor.

A total of 18 credits are needed to complete the Explosive Engineering Minor Program. This is the preferred route for students that would like to specialize in explosive engineering. The first three (required) courses will provide the students with basic knowledge in explosive engineering. The subsequent courses will give students a view into the mining and geotechnical applications of explosive engineering, such as with surface mining, underground mining, or underground construction.

REQUIRED FOR ALL STUDENTS:		**9.0**
MNGN333	EXPLOSIVES ENGINEERING I (REQUIRED FOR ALL STUDENTS:)	
MNGN407	ROCK FRAGMENTATION (REQUIRED FOR ALL STUDENTS:)	
MNGN444	EXPLOSIVES ENGINEERING II (REQUIRED FOR ALL STUDENTS:)	
AT LEAST THREE COURSES FROM THE FOLLOWING:		**9.0**
MNGN210	INTRODUCTORY MINING	
MNGN308	MINE SAFETY	
MNGN309	MINE SAFETY AND OPERATIONS	
MNGN312	SURFACE MINE DESIGN	
MNGN314	UNDERGROUND MINE DESIGN	
MNGN316	COAL MINING METHODS	
MNGN321	INTRODUCTION TO ROCK MECHANICS	
MNGN404	TUNNELING	
MNGN405	ROCK MECHANICS IN MINING	
MNGN406	DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS	

MNGN408	UNDERGROUND DESIGN AND CONSTRUCTION	
MNGN499	INDEPENDENT STUDY	
Total Semester Hrs		**18.0**

Space Mining Minor

Program Advisor: Dr. Jamal Rostami

Students enrolled in this program will gain insight into the basic knowledge in planetary geology, exploration methods, and resource/reserve estimation and valuation. In addition, they will also gain practical knowledge in applications of various equipment necessary for excavation and the production of basic materials needed to build sustainable habitats and infrastructures. Program advisors include the faculty members of the Mining Engineering Department and those of the Center for Space Resources (CSR). They will advise students in the selection of a proper course sequence and guide them to complete projects.

A total of six courses or 18 credits is required to complete a minor in Space Mining in the department of Mining Engineering. This minor program will prepare students to further specialize in ISRU engineering. The first three required courses will provide the students with basic knowledge related to space resources. The subsequent courses will give students applied knowledge in more focused areas in space mining.

Required for all students:		9.0
MNGN210	INTRODUCTORY MINING	
GEOL410	PLANETARY GEOLOGY	
SPRS401	SPACE RESOURCES FUNDAMENTALS	
At least three courses from the list below		9.0
Total Semester Hrs		**18.0**

At least three of courses from the following list are needed to complete a minor in Space Mining:		**9.0**
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	
EBGN321	ENGINEERING ECONOMICS	
EDNS430	CORPORATE SOCIAL RESPONSIBILITY	
GEGN403	MINERAL EXPLORATION DESIGN	
GEOL470	APPLICATIONS OF SATELLITE REMOTE SENSING	
MNGN312	SURFACE MINE DESIGN	
MNGN321	INTRODUCTION TO ROCK MECHANICS	
MNGN322	INTRODUCTION TO MINERAL PROCESSING AND LABORATORY	
MNGN333	EXPLOSIVES ENGINEERING I	
MNGN335	COMMUNITIES AND NATURAL RESOURCE DEVELOPMENT	
MNGN407	ROCK FRAGMENTATION	
MNGN427	MINE VALUATION	
MTGN461	TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS	
MTGN462	SOLID WASTE MINIMIZATION AND RECYCLING	
MNGN470	SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY	
MNGN498	DATA ANALYTICS FOR RESOURCES ENGINEERING	
MNGN502	GEOSPATIAL BIG DATA ANALYTICS	
MNGN567	SUSTAINABLE DEVELOPMENT AND EARTH RESOURCES	
MNGN570	SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY	
MEGN441	INTRODUCTION TO ROBOTICS	

Courses

MNGN198. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) (WI) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN203. SOFTWARE FUNDAMENTALS FOR 3D DATA ANALYSIS AND MINE PLANNING. 1.0 Semester Hr.
Software Fundamentals for 3D Data Analysis and Mine Planning. This course is designed to provide an introduction to geologic data set coming from mining exploration project, 3D visualization of sub-surface information representing geologic rock types, lithologies, alterations, and grades, and creation of solid models of geologic domains followed by statistical analysis of 3D subsurface data, interpretation of grade information into block models for economic valuation, pit limit analysis and mine planning using a commercial software package called MinePlan software from Hexagon Mining. Prerequisite: MNGN210 or instructor consent.
Course Learning Outcomes

- Master the basics of MinePlan software’s menus, pulldowns, and features and options
- Master the basics of MinePlan software’s 3D visualization tool “MS3D”
- Master the basics of MinePlan software’s Statistical tool “Sigma”
- Master the basics of MinePlan software’s 3D Modelling tool
- Master the basics of MinePlan softwares pit design and evaluation tool “MineEval”

MNGN205. MINING ENGINEERING FIELD EXPERIENCE. 1.0 Semester Hr.
The objectives of this course are to provide the student with a fundamental understanding of mine operations, exploration, mineral processing, and the importance of safety, social and community factors, and environmental stewardship through hands-on exercises and tours of mines, processing facilities, and industry-relevant sites. The curriculum within this course has been designed to expose students to a wide array of experiences and provide insights that will aid them in upper-division courses. Prerequisite: MNGN 210, MNGN 308 or instructor consent.
Course Learning Outcomes

- Basic life cycle of a mining property
- The factors that influence a successful mining operation

- The legal and regulatory responsibilities mines operate under
- The importance of exploration and resource delineation/reporting,
- Basic unit operations and mine design considerations
- Social, environmental, and workplace responsibilities
- The economics associated with the marketing and sales of mineral commoditie

MNGN210. INTRODUCTORY MINING. 3.0 Semester Hrs.
INTRODUCTORY MINING (I, II) Survey of mining and mining economics. Topics include mining law, exploration and sampling, reserve estimation, project evaluation, basic unit operations including drilling, blasting, loading and hauling, support, shaft sinking and an introduction to surface and underground mining methods. Prerequisite: None. 3 hours lecture; 3 semester hours.

MNGN222. INTRODUCTION TO EXPLOSIVES ENGINEERING. 3.0 Semester Hrs.
A basic introduction to explosives engineering and applied explosives science for students that recently completed their freshman or sophomore years at CSM. Topics covered will include safety and explosives regulations, chemistry of explosives, explosives physics, and detonation properties. The course features a significant hands-on practical laboratory learning component with several sessions held at the Explosives Research Laboratory (ERL) in Idaho Springs. Students completing this course will be well prepared for more advanced work in MNGN333 and MNGN444. Prerequisites: PHGN100, CHGN121, CHGN122, MATH111, and MATH112. 2 hours lecture; 3 hours lab; 3 semester hours.
Course Learning Outcomes

- Primary: Knowledge, Analysis, Design and Operation; Secondary: Open-ended and Teams

MNGN251. METALLURGICAL AND MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.
Applications of thermodynamics in extractive and physical metallurgy and materials science. Thermodynamics of solutions including solution models and thermodynamic properties of alloys and slags. Reaction equilibria with examples in alloy systems and slags. Phase stability analysis. Thermodynamic properties of binary alloys in the solid state, defect equilibrium, and interactions. Prerequisite: MATH112, CHGN122 or CHGN125, PHGN100.

MNGN298. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) (WI) Individual research or special problem projects supervised by a faculty member. When a student and instructor agree on a subject matter, content, method of assessment, and credit hours, it must be approved by the Department Head. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN301. MINE SURVEYING. 2.0 Semester Hrs.
Lectures and hands-on fieldwork to teach students the modern methods of mine surveying applicable to underground mining. This course will familiarize students with the tools and techniques needed to perform underground traversing including balancing of loop surveys, setting out points, establishing line and grade. (10 days) Prerequisite: MNGN210, MNGN308 or instructor consent.

Course Learning Outcomes

- Students should know and apply the basic principles of measuring and locating lines, elevations, and angles on the earth's surface.
- Students should know and apply the basic principles of modern underground and surface mine surveying using basic Brunton compass and modern total station instruments.

MNGN308. MINE SAFETY. 1.0 Semester Hr.
Causes and prevention of accidents. Mine safety regulations. Mine rescue training. Safety management and organization. 1 hour lecture; 1 semester hour. Taken as the first week of summer session. Prerequisite: MNGN210.

MNGN309. MINE SAFETY AND OPERATIONS. 2.0 Semester Hrs.
Training in practical mine labor functions including: operation of jackleg drills, jumbo drills, muckers, and LHD machines. Training stresses safe operation of equipment and safe handling of explosives. Introduction to front-line management techniques. 2 semester hours. Prerequisite: MNGN210 and MSHA part 48, 40-hour training and 5000.23 certificate.
Course Learning Outcomes

MNGN310. EARTH MATERIALS. 3.0 Semester Hrs.
Introduction to Earth Materials, emphasizing the structure, formation, distribution and engineering behavior of minerals and rocks. Structural features and processes are related to stress/strain theory and rock mechanics principles. Laboratories and field exercises emphasize the recognition, description and engineering evaluation of natural materials. Lectures and case study exercises present the knowledge of natural materials and processes necessary for mining engineering careers. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: GEGN101.
Course Learning Outcomes

- see attached document

MNGN311. MINING GEOLOGY. 3.0 Semester Hrs.
Introduction to Mining Geology, emphasizing the formation, distribution, engineering behavior, exploration for and geological aspects of development of ore materials. Laboratories emphasize the recognition, description and engineering evaluation of ores and their hosts. Lectures and case study exercises present the knowledge of ores and ore-forming processes necessary for mining engineering careers. Prerequisites: GEGN 101, (GEOL310 or MNGN310). 2 hours lecture; 3 hours lab: 3 semester hours.
Course Learning Outcomes

- n/a

MNGN312. SURFACE MINE DESIGN. 3.0 Semester Hrs.
Analysis of elements of surface mine operation and design of surface mining system components with emphasis on minimization of adverse environmental impact and maximization of efficient use of mineral resources. Ore and coal estimates, unit operations, equipment selection, final pit determinations, short- and longrange planning, road layouts, dump planning, and cost estimation. Prerequisite: MNGN210.
Course Learning Outcomes

MNGN314. UNDERGROUND MINE DESIGN. 3.0 Semester Hrs.
Selection, design, and development of most suitable underground mining methods based upon the physical and the geological properties of mineral deposits (coal, metallics and nonmetallics), conservation considerations, and associated environmental impacts. Reserve estimates, development and production planning, engineering drawings for development and extraction, underground haulage systems, and cost

estimates. 2 hours lecture, 3 hours lab; 3 semester hours. Prerequisite: MNGN210.

Course Learning Outcomes

MNGN316. COAL MINING METHODS. 3.0 Semester Hrs.

(WI) Devoted to surface and underground coal mining methods and design. The surface mining portion emphasizes area-mining methods, including pertinent design-related regulations, and overburden removal systems. Pit layout, sequencing, overburden equipment selection and cost estimation are presented. The underground mining portion emphasizes general mine layout; detailed layout of continuous, conventional, longwall, and shortwall sections. General cost and manning requirements; and production analysis. Federal and state health and safety regulations are included in all aspects of mine layout. Pre - requisite: MNGN210. 2 hours lecture, 3 hours lab, 3 semester hours.

MNGN317. DYNAMICS FOR MINING ENGINEERS. 1.0 Semester Hr.

For mining engineering majors only. Absolute and relative motions, kinetics, work-energy, impulse-momentum and angular impulse-momentum. 1 hour lecture; 1 semester hour. Prerequisite: MATH213/223, CEEN241.

MNGN318. STATICS AND DYNAMICS COMBINED FOR MN. 4.0 Semester Hrs.

This course will cover: (for statics) forces, moments, couples, equilibrium, centroids and second moments of areas, volumes and masses, hydrostatics, friction; and (for dynamics) particle kinematics (including 2-D motion in x-y coordinates, normal-tangential coordinates, & polar coordinates), rigid body kinematics (Including relative velocities and accelerations), rigid body kinetics (including the equation of motion, work and energy, linear impulse-momentum, & angular momentum). Particle kinematics (including 2-D motion in x-y coordinates, normal-tangential coordinates, & polar coordinates), rigid body kinematics (Including relative velocities and accelerations), rigid body kinetics (including the equation of motion, work and energy, linear impulse-momentum, & angular momentum). Prerequisite: PHGN100, MATH213.

Course Learning Outcomes

- Identify and discuss fundamental concepts of forces, moments, pressures, mass, and gravity
- Calculate forces and moments acting on simple and complex structures, equilibrium of forces and moments
- Calculate forces and moments using centroid and center of gravity concepts
- Identify and discuss statically indeterminate equilibria
- Apply concepts of statics to mining machines and structures
- Compare and contrast translational and rotational motion, equivalence, calculations
- Apply dynamics concepts to mining machinery

MNGN321. INTRODUCTION TO ROCK MECHANICS. 3.0 Semester Hrs.

Physical properties of rock, and fundamentals of rock substance and rock mass response to applied loads. Principles of elastic analysis and stress-strain relationships. Elementary principles of the theoretical and applied design of underground openings and pit slopes. Emphasis on practical applied aspects. 2 hours lecture, 3 hours lab; 3 semester hours. Prerequisite: CEEN311, MNGN318 or CEEN241.

MNGN322. INTRODUCTION TO MINERAL PROCESSING AND LABORATORY. 3.0 Semester Hrs.

Principles and practice of crushing, grinding, size classification; mineral concentration technologies including magnetic and electrostatic separation, gravity separation, and flotation. Sedimentation, thickening, filtration and product drying as well as tailings disposal technologies are included. The course is open to all CSM students. Prerequisite: PHGN200/ 210, MATH213/223. 2 hours lecture; 3 hours lab; 3 semester hours.

MNGN333. EXPLOSIVES ENGINEERING I. 3.0 Semester Hrs.

(I) This course gives students in engineering and applied sciences the opportunity to examine and develop a fundamental knowledge including terminology and understanding of explosives science and engineering concepts. Student learning will be demonstrated by assignments, quizzes, and exams. Learning assistance will come in the form of multidisciplinary lectures complemented by a few lectures from experts from government, industry and the explosives engineering community. Pre-requisites: None. 2 hours lecture; 3 hours lab. 3 semester hours.

Course Learning Outcomes

- Primary: Knowledge, Analysis, and Design and Operation; Secondary: Open-ended and Teams

MNGN334. CHEMICAL PROCESSING OF MATERIALS. 3.0 Semester Hrs.

Development and application of fundamental principles related to the processing of metals and materials by thermochemical, aqueous, and fused salt electrochemical/chemical routes. The course material is presented within the framework of a formalism that examines the physical chemistry, thermodynamics, reaction mechanisms and kinetics inherent to a wide selection of chemical processing systems. The general formalism provides for a transferable knowledge-base to other systems not specifically covered in the course. Prerequisite: MTGN272, MTGN251, CEEN267 or EDNS251. Co-requisite: MTGN334L.

MNGN335. COMMUNITIES AND NATURAL RESOURCE DEVELOPMENT. 3.0 Semester Hrs.

This course examines the relationship between humans and their environment across space and time. In particular, it focuses on the intersections between natural resource developments and communities. By incorporating theoretical perspectives from environmental anthropology, it draws from frameworks of political ecology, social and environmental justice, indigenous rights, disasters, vulnerability, natural resource management, unequal development, and environmental futures. Drawing from case studies from mining, oil and gas, and energy developments, students will gain knowledge and skills in evaluating how natural resource developments and communities coexist.

Course Learning Outcomes

- 1. Apply interdisciplinary analyses to examining how communities and the natural environment are intimately related.
- 2. Demonstrate their understanding of the “community concept” by applying critical thinking to the ways we conceptualize communities
- 3. Be able to articulate the ways in which natural resources are social constructions.
- 4. Describe the concept of sustainable development and its role in natural resource developments contexts.
- 5. Research, write about, and present a variety case studies on the relationship between communities and natural resource developments in different contexts.
- 6. Articulate the engineer’s role in issues and case studies related to communities and natural resource developments.

MNGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

MNGN350. INTRODUCTION TO GEOTHERMAL ENERGY. 3.0 Semester Hrs.

Geothermal energy resources and their utilization, based on geoscience and engineering perspectives. Geoscience topics include world wide occurrences of resources and their classification, heat and mass transfer, geothermal reservoirs, hydrothermal geochemistry, exploration methods, and resource assessment. Engineering topics include thermodynamics of water, power cycles, electricity generation, drilling and well measurements, reservoir-surface engineering, and direct utilization. Economic and environmental considerations and case studies are also presented. Prerequisites: ENGY200. 3 hours lecture; 3 semester hours.

MNGN398. SPECIAL TOPICS IN MINING ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) (WI)) Individual research or special problem projects supervised by a faculty member. When a student and instructor agree on a subject matter, content, method of assessment, and credit hours, it must be approved by the Department Head. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN404. TUNNELING. 3.0 Semester Hrs.

(I) Modern tunneling techniques. Emphasis on evaluation of ground conditions, estimation of support requirements, methods of tunnel driving and boring, design systems and equipment, and safety. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN405. ROCK MECHANICS IN MINING. 3.0 Semester Hrs.

The course deals with the rock mechanics aspect of design of mine layouts developed in both underground and surface. Underground mining sections include design of coal and hard rock pillars, mine layout design for tabular and massive ore bodies, assessment of caving characteristics or ore bodies, performance and application of backfill, and phenomenon of rock burst and its alleviation. Surface mining portion covers rock mass characterization, failure modes of slopes excavated in rock masses, probabilistic and deterministic approaches to design of slopes, and remedial measures for slope stability problems. Prerequisite: MN321 or equivalent. 3 hours lecture; 3 semester hours.

MNGN406. DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS. 3.0 Semester Hrs.

Design of underground excavations and support. Analysis of stress and rock mass deformations around excavations using analytical and numerical methods. Collections, preparation, and evaluation of in situ and laboratory data for excavation design. Use of rock mass rating systems for site characterization and excavation design. Study of support types and selection of support for underground excavations. Use of numerical models for design of shafts, tunnels and large chambers. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN407. ROCK FRAGMENTATION. 3.0 Semester Hrs.

Theory and application of rock drilling, rock boring, explosives, blasting, and mechanical rock breakage. Design of blasting rounds, applications to surface and underground excavation. Prerequisite: CEEN241, concurrent enrollment. 3 hours lecture; 3 semester hours.

MNGN408. UNDERGROUND DESIGN AND CONSTRUCTION. 2.0 Semester Hrs.

Soil and rock engineering applied to underground civil works. Tunneling and the construction of underground openings for power facilities, water conveyance, transportation, and waste disposal; design, excavation and support of underground openings. Emphasis on consulting practice, case studies, geotechnical design, and construction methods. Prerequisite: CEEN312 OR MNGN321. 2 hours of lecture; 2 semester hours.

MNGN410. EXCAVATION PROJECT MANAGEMENT. 2.0 Semester Hrs.

Successful implementation and management of surface and underground construction projects, preparation of contract documents, project bidding and estimating, contract awarding and notice to proceed, value engineering, risk management, construction management and dispute resolution, evaluation of differing site conditions claims. Prerequisite: MNGN 210, 2-hour lecture, 2 semester hours.

MNGN414. MINE PLANT DESIGN. 3.0 Semester Hrs.

Analysis of mine plant elements with emphasis on design. Materials handling, dewatering, hoisting, belt conveyor and other material handling systems for underground mines. Prerequisite: MNGN312 and MNGN314. 2 hours lecture, 3 hours lab; 3 semester hour.

Course Learning Outcomes

- Not Changing

MNGN418. ADVANCED ROCK MECHANICS. 3.0 Semester Hrs.

Equivalent with MNGN508,

Analytical and numerical modeling analysis of stresses and displacements induced around engineering excavations in rock. In-situ stress. Rock failure criteria. Complete load deformation behavior of rocks. Measurement and monitoring techniques in rock mechanics. Principles of design of excavation in rocks. Analytical, numerical modeling and empirical design methods. Probabilistic and deterministic approaches to rock engineering designs. Excavation design examples for shafts, tunnels, large chambers and mine pillars. Seismic loading of structures in rock. Phenomenon of rock burst and its alleviation. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours.

MNGN421. DESIGN OF UNDERGROUND EXCAVATIONS. 3.0 Semester Hrs.

Design of underground openings in competent and broken ground using rock mechanics principles. Rock bolting design and other ground support methods. Coal, evaporite, metallic and nonmetallic deposits included. Prerequisite: MNGN321, concurrent enrollment. 3 hours lecture; 3 semester hours.

MNGN422. FLOTATION. 2.0 Semester Hrs.

Science and engineering governing the practice of mineral concentration by flotation. Interfacial phenomena, flotation reagents, mineral-reagent interactions, and zeta-potential are covered. Flotation circuit design and evaluation as well as tailings handling are also covered. The course also includes laboratory demonstrations of some fundamental concepts. 3 hours lecture; 3 semester hours.

MNGN423. FLOTATION LABORATORY. 1.0 Semester Hr.

Experiments to accompany the lectures in MNGN422. Co-requisite: MNGN421. 3 hours lab; 1 semester hour.

MNGN424. MINE VENTILATION. 3.0 Semester Hrs.

Fundamentals of mine ventilation, including control of gas, dust, temperature, and humidity; ventilation network analysis and design of systems. Prerequisites: PEGN251 or MEGN351, CHGN209 or MEGN261, and MNGN314. 2 hours lecture, 3 hours lab; 3 semester hours.

Course Learning Outcomes

- See right

MNGN425. MINE VENTILATION AND THERMODYNAMICS. 4.0 Semester Hrs.

Fundamentals of mine ventilation and thermodynamics, including heat transfer, flow and control of gas, dust, temperature, and humidity; ventilation network analysis and design of mine ventilation systems. Prerequisite: MNGN314, EGGN351 or PEGN251 or instructor consent.

Course Learning Outcomes

- • define basic concepts and principles of thermodynamics, heat, energy and work (a)
- • know and apply, in examples, the first and second laws of thermodynamics, mass and energy balances (a)
- • perform fundamental calculations in heat transfer through conduction, convection and radiation (a, b)
- • explain the fundamentals of gas cycle processes as they apply to internal combustion engines, gas turbines, compressors and refrigeration machines (a)
- • apply mine ventilation concepts properly ventilate underground coal, metal and non-metal mines (b, e)
- • dilute and render harmless concentrations of toxic and explosive gases (e)
- • maintain respirable dust standards through adequate ventilation, use of water sprays and other engineering controls (b, e)
- • Maintain diesel particulate matter (DPM) standards through adequate ventilation and engine emission control technologies (b, e)
- • use computer simulation programs to solve mine ventilation network problems and to improve mine ventilation conditions (b, c, e, g, k)
- • communicate effectively about mine ventilation needs, methods, fire and explosion prevention measures, air conditioning and dust control. (c, e, g, k)

MNGN426. HYDRO- AND ELECTRO-METALLURGY. 3.0 Semester Hrs.

Physicochemical principles associated with the extraction and refining of metals by hydro- and electrometallurgical techniques. Discussion of unit processes in hydrometallurgy, electrowinning, and electrorefining. Analysis of integrated flowsheets for the recovery of nonferrous metals. Prerequisite: MTGN334, MTGN352, MTGN351 or MTGN251. Co-requisite: MTGN461.

MNGN427. MINE VALUATION. 2.0 Semester Hrs.

(II) Course emphasis is on the business aspects of mining. Topics include time valuation of money and interest formulas, cash flow, investment criteria, tax considerations, risk and sensitivity analysis, escalation and inflation and cost of capital. Calculation procedures are illustrated by case studies. Computer programs are used. Prerequisite: Senior in Mining, graduate status. 2 hours lecture; 2 semester hours.

MNGN428. MINING ENGINEERING EVALUATION AND DESIGN REPORT I. 1.0 Semester Hr.

Preparation of Phase I engineering report based on coordination of all previous work. Includes mineral deposit selection, geologic description, mining method selection, ore reserve determination, and permit process outline. Emphasis is on detailed mine design and cost analysis evaluation in preparation for MNGN429. Prerequisite: MNGN210, MNGN203, MNGN308, MNGN312, MNGN314, MNGN309, MNGN321, GEOL310, GEOL311. Co-requisite: MNGN438.

Course Learning Outcomes

- Same

MNGN429. MINING ENGINEERING EVALUATION AND DESIGN REPORT II. 2.0 Semester Hrs.

(WI) Preparation of formal engineering report based on all course work in the mining option. Emphasis is on mine design, equipment selection, production scheduling, evaluation and cost analysis. Prerequisite: MNGN428, MNGN210, MNGN300, MNGN308, MNGN312, MNGN314, MNGN309, MNGN321, MNGN316, GEOL310, GEOL311, MNGN438, MNGN414. Co-requisites: MNGN322, MNGN427, and MNGN433. 2 hours lecture; 2 semester hours.

Course Learning Outcomes

- Same

MNGN430. PHYSICAL CHEMISTRY OF IRON AND STEELMAKING. 3.0 Semester Hrs.

Physical chemistry principles of blast furnace and direct reduction production of iron and refining of iron to steel. Discussion of raw materials, productivity, impurity removal, deoxidation, alloy additions, and ladle metallurgy. Prerequisite: MTGN334, MTGN251 or MTGN351.

MNGN431. MINING AND METALLURGICAL ENVIRONMENT. 3.0 Semester Hrs.

This course covers studies of the interface between mining and metallurgical process engineering and environmental engineering areas. Wastes, effluents and their point sources in mining and metallurgical processes such as mineral concentration, value extraction and process metallurgy are studied in context. Fundamentals of unit operations and unit processes with those applicable to waste and effluent control, disposal and materials recycling are covered. Engineering design and engineering cost components are also included for some examples chosen. The ratio of fundamentals applications coverage is about 1:1. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN432. PYROMETALLURGY. 3.0 Semester Hrs.

Extraction and refining of metals including emerging practices. Modifications driven by environmental regulations and by energy minimization. Analysis and design of processes and the impact of economic constraints. Prerequisite: MTGN334.

MNGN433. MINE SYSTEMS ANALYSIS I. 3.0 Semester Hrs.

Application of statistics, systems analysis, and operations research techniques to mineral industry problems. Laboratory work using computer techniques to improve efficiency of mining operations. Prerequisite: Senior or graduate status. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN434. PROCESS ANALYSIS. 1.0 Semester Hr.

Projects to accompany the lectures in MNGN422. Prerequisite: MNGN422. 3 hours lab; 1 semester hour.

MNGN436. UNDERGROUND COAL MINE DESIGN. 3.0 Semester Hrs.

Design of an underground coal mine based on an actual coal reserve. This course shall utilize all previous course material in the actual design of an underground coal mine. Ventilation, materials handling, electrical transmission and distribution, fluid mechanics, equipment selection and application, mine plant design. Information from all basic mining survey courses will be used. Prerequisite: MNGN316, MNGN321, MNGN414, EGGN329 and MNGN381 or MNGN384. 3 hours lecture, 3 hours lab; 3 semester hours.

MNGN438. GEOSTATISTICS. 3.0 Semester Hrs.
Introduction to elementary probability theory and its applications in engineering and sciences; discrete and continuous probability distributions; parameter estimation; hypothesis testing; linear regression; spatial correlations and geostatistics with emphasis on applications in earth sciences and engineering. Prerequisites: MATH112. 2 hours of lecture and 3 hours of lab. 3 semester hours.

MNGN440. EQUIPMENT REPLACEMENT ANALYSIS. 2.0 Semester Hrs.
Introduction to the fundamentals of classical equipment replacement theory. Emphasis on new, practical approaches to equipment replacement decision making. Topics include: operating and maintenance costs, obsolescence factors, technological changes, salvage, capital investments, minimal average annual costs, optimum economic life, infinite and finite planning horizons, replacement cycles, replacement vs. expansion, maximization of returns from equipment replacement expenditures. Prerequisite: MNGN427, senior or graduate status. 2 hours lecture; 2 semester hours.

MNGN444. EXPLOSIVES ENGINEERING II. 3.0 Semester Hrs.
This course gives students in engineering and applied sciences the opportunity to acquire the fundamental concepts of explosives engineering and science applications as they apply to industry and real life examples. Students will expand upon their MNGN333 knowledge and develop a more advanced knowledge base including an understanding of the subject as it applies to their specific project interests. Assignments, quizzes, concept modeling and their project development and presentation will demonstrate student's progress. Prerequisite: MNGN333. 2 hours lecture, 3 hours lab, 3 semester hours.
Course Learning Outcomes

- Primary: Knowledge, Analysis, and Design and Operation; Secondary: Open-ended and Teams

MNGN445. ROCK SLOPE ENGINEERING. 3.0 Semester Hrs.
Introduction to the analysis and design of slopes excavated in rock. Rock mass classification and strength determinations, geological structural parameters, properties of fracture sets, data collection techniques, hydrological factors, methods of analysis of slope stability, wedge intersections, monitoring and maintenance of final pit slopes, classification of slides. Deterministic and probabilistic approaches in slope design. Remedial measures. Laboratory and field exercise in slope design. Collection of data and specimens in the field for deterring physical properties required for slope design. Application of numerical modeling and analytical techniques to slope stability determinations for hard rock and soft rock environments. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN452. SOLUTION MINING AND PROCESSING OF ORES. 3.0 Semester Hrs.
(II) Theory and application of advanced methods of extracting and processing of minerals, underground or in situ, to recover solutions and concentrates of value-materials, by minimization of the traditional surface processing and disposal of tailings to minimize environmental impacts. Prerequisite: Senior or graduate status; none. 3 hours lecture; 3 semester hours. Offered in spring.

MNGN460. INDUSTRIAL MINERALS PRODUCTION. 3.0 Semester Hrs.
This course describes the engineering principles and practices associated with quarry mining operations related to the cement and aggregates industries. The course will cover resource definition, quarry planning and design, extraction, and processing of material for cement and aggregate production. Permitting issues and reclamation, particle sizing and environmental practices, will be studied in depth. Prerequisite: MNGN312, MNGN322. 3 hours lecture; 3 semester hours. Offered in spring.

MNGN461. TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS. 3.0 Semester Hrs.
Introduction to the conserved-quantities: momentum, heat, and mass transfer, and application of chemical kinetics to elementary reactor-design. Examples from materials processing and process metallurgy. Molecular transport properties: viscosity, thermal conductivity, and mass diffusivity of materials encountered during processing operations. Uni-directional transport: problem formulation based on the required balance of the conserved- quantity applied to a control-volume. Prediction of velocity, temperature and concentration profiles. Equations of change: continuity, motion, and energy. Transport with two independent variables (unsteady-state behavior). Interphase transport: dimensionless correlations friction factor, heat, and mass transfer coefficients. Elementary concepts of radiation heat-transfer. Flow behavior in packed beds. Design equations for: continuous- flow/batch reactors with uniform dispersion and plug flow reactors. Digital computer methods for the design of metallurgical systems. Prerequisite: MATH225, MTGN334, MTGN352.

MNGN462. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.
This course will examine, using case studies, how industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisite: CEEN301, CEEN302,CHGN403.

MNGN470. SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY. 3.0 Semester Hrs.
(I) Fundamentals of managing occupational safety and health at a mining operation. Includes tracking of accident and injury statistics, risk management, developing a safety and health management plan, meeting MSHA regulatory requirements, training, safety audits and accident investigations. 3 hours lecture; 3 semester hours.

MNGN482. MINE MANAGEMENT. 3.0 Semester Hrs.
(II) Basic principles of successful mine management including supervision skills, administrative policies, industrial and human relations, improvement engineering, risk management, conflict resolution and external affairs. Prerequisite: Senior or graduate status. 2 hours lecture and 1 hour case study presentation and discussion per week; 3 hours lecture; 3 semester hours.

MNGN490. ENERGY AND SOCIETY. 3.0 Semester Hrs.
Equivalent with ENGY490,LAIS490,
A transdisciplinary capstone seminar that explores a spectrum of approaches to the understanding, planning, and implementation of energy production and use, including those typical of diverse private and public (national and international) corporations, organizations, states, and agencies. Aspects of global energy policy that may be considered include the historical, social, cultural, economic, ethical, political, and environmental aspects of energy together with comparative methodologies and assessments of diverse forms of energy development. Prerequisites: EBGN330 and one of either ENGY310, ENGY320, or ENGY340. 3 hours lecture/seminar; 3 semester hours.

MNGN498. SPECIAL TOPICS IN MINING ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) (WI) Individual research or special problem projects supervised by a faculty member. When a student and instructor agree on a subject matter, content, method of assessment, and credit hours, it must be approved by the Department Head. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Department Head

Bill Zisch

Associate Department Head

H. Sebnem Duzgun

Professors

Corby Anderson

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Hugh B. Miller

Nicole Smith

Gabriel Walton

Teaching Assistant Professor

Heather Lammers

Professors of Practice

Paul Zink

Research Professor

D. Erik Spiller

Research Assistant Professor

Aaron Malone

Petroleum Engineering

Program Description

The primary objectives of petroleum engineering are the safe and environmentally sound exploration, evaluation, development, and recovery of oil, gas, geothermal, and other fluids in the earth. Skills in this branch of engineering are needed to meet the world's ever-increasing demand for hydrocarbon fuel, thermal energy, and waste and pollution management.

Graduates of our program are in solid demand, with the petroleum industry offering a wide range of employment opportunities for Petroleum Engineering students during summer breaks and after graduation. Exciting experiences range from field work in drilling and producing oil and gas fields, to office jobs in small towns or large cities. Worldwide travel and overseas assignments are available for interested students.

One of our objectives in the Petroleum Engineering department is to prepare students to succeed in an energy industry that is evolving into an industry working with many energy sources. In addition to developing technical competence in petroleum engineering, you will learn how your education can help you contribute to the development of alternative energy sources such as geothermal and carbon sequestration. Alternative careers exist outside of the petroleum industry too and many petroleum engineering graduates find rewarding careers in the environmental arena, law, medicine, business, and many other walks of life.

The department offers semester abroad opportunities through formal exchange programs with the Petroleum Engineering Department at the Montanuniversität Leoben in Austria, Technical University in Delft, Holland, King Fahd University of Petroleum Minerals (KFUPM) in Dhahran, Saudi Arabia and the Petroleum Institute in Abu Dhabi, UAE. Qualified undergraduate and graduate students from each school can attend the other for one semester and receive full transfer credit back at the home university.

The Bachelor of Science in Petroleum Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission’s General Criteria and Program Criteria for Petroleum Engineering.

Graduate courses emphasize the research aspects of the profession, as well as advanced engineering applications. Qualified students may continue their education and earn a Master of Science, Master of Engineering, and Doctor of Philosophy degrees.

To facilitate classroom instruction and the learning experience, the Petroleum Engineering faculty recommend that all petroleum engineering students have notebook computers. Recommended specifications for the computer can be obtained from the CSM Academic Computing & Networking webpage.

The Petroleum Engineering Department encourages student involvement with the Society of Petroleum Engineers, the American Association of Drilling Engineers, and the American Rock Mechanics Association. The department provides some financial support for students attending the annual technical conferences for these professional societies.

Marquez (pronounced "Marcus") Hall is home to the Petroleum Engineering Department. A prominent campus landmark, Marquez Hall showcases Mines’ long-standing strengths in its core focus areas and our commitment to staying at the forefront of innovation. The building is designed using aggressive energy saving strategies and is LEED certified. Marquez Hall is the first building on the Colorado School of Mines Campus that is funded entirely by private donations.

Available laboratory and computer equipment include:

Computer Laboratory

This computer laboratory is available for general use and classroom instruction. It is continuously open for student use. Software includes more than $5 million in donated industry software used by oil and gas companies and research labs around the world.

Drilling Simulator Laboratory

Rare on university campuses, this lab contains an up-to-date computer controlled, full-scale, graphic-intensive drilling rig simulator. It includes drilling controls that can be used to simulate onshore and offshore drilling operations and well control situations. This lab also has three small-scale drilling rig simulators, identical to those used in industrial well control training facilities.

Reservoir Characterization Laboratory

Rock properties are measured that affect economic development of reservoir resources of oil and gas. Measured properties include permeability, porosity, and relative permeability. Hands on experiences with simple and sophisticated equipment are provided.

Drilling Fluids Laboratory

Modern equipment found on drilling rigs worldwide enables students to evaluate and design fluid systems required in drilling operations.

Fluids Characterization Laboratory

A variety of properties of fluids from oil and gas reservoirs are measured for realistic conditions of elevated temperature and pressure. This laboratory accentuates principles studied in lectures.

Petroleum Engineering Summer Sessions

Two summer sessions, one after the completion of the sophomore year and one after the junior year, are important parts of the educational experience. The first is a session designed to introduce the student to the petroleum industry. Various career opportunities are highlighted as well as showing petroleum field and office operations and geology. In addition, students are indoctrinated in health, safety, and environmental awareness. Petroleum Engineering, a truly unique and exciting engineering discipline, can be experienced by visiting petroleum operations. Historically, the areas visited have included Europe, Alaska, Canada, the U.S. Gulf Coast, California, the Midcontinent, the northeast U.S., and the Rocky Mountain Region.

The second two-week session after the junior year is an in-depth study of the Rangely Oil Field and surrounding geology in Western Colorado. The Rangely Oil Field is the largest oil field in the Rocky Mountain region and has undergone primary, secondary, and enhanced recovery processes. Field work in the area provides the setting for understanding the complexity of geologic systems and the environmental and safety issues in the context of reservoir development and management.

Other Opportunities

It is recommended that all students considering majoring or minoring in Petroleum Engineering sign up for the Introductory course PEGN201, Petroleum Engineering Fundamentals, as soon as possible in their schedules. Also, seniors may take 500-level graduate courses that include topics such as drilling, reservoir, and production engineering; reservoir simulation and characterization, and economics and risk analysis with instructor concurrence (see the CSM Graduate Catalog for course offerings).

Program Educational Objectives (Bachelor of Science in Petroleum Engineering)

The Mission of the Petroleum Engineering program continues to evolve over time in response to the needs of the graduates and industry; in concert with the Colorado School of Mines Institutional Mission Statement and the Profile of the Future Graduate. The Mission of the Petroleum Engineering Program is:

Our mission is to provide the necessary skills at the undergraduate, graduate, and continuing education levels to serve the world in developing conventional and unconventional hydrocarbon resources, water resources, and geothermal energy, while promoting cutting-edge research to improve resource recovery, advancing technologies to combat environmental problems, such as carbon sequestration and other earth disposal processes, and to foster the socially responsible development of Earth’s resources.

As part of that process, the faculty of the department has objectives that they want to see their alumni accomplish within three to five years from graduation. The Petroleum Engineering department's faculty and other constituents have affirmed the following Program Educational Objectives:

- Obtain an industry, government, or academic position in petroleum engineering, or a related field, or be pursuing a graduate education in petroleum engineering or in a related field.
- Demonstrate advancement in their chosen careers and exercising leadership in the area of petroleum engineering.
- Continue to develop personally and professionally, and serve others, through continuing education, professional societies, educational institutions, community groups, and other organizations.
- Identify the ethical implications and social impacts of engineering decisions.

To accomplish these objectives, the Petroleum Engineering program has, in addition to the school's graduate profile and the overall objectives, certain student objectives particular to the department and based on the ABET Student Outcomes including:

- an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- an ability to communicate effectively with a range of audiences
- an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

- an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

These program educational objectives and student outcomes can be found on the Petroleum Engineering Department's webpage under the Colorado School of Mines website. These are also found publicly posted in the ABET bulletin board outside the department offices.

Curriculum

All disciplines within petroleum engineering are covered to great depth at the undergraduate and graduate levels, both in the classroom and laboratory instruction, and in research. Specific areas include fundamental fluid and rock behavior, drilling, formation evaluation, well completions and stimulation, well testing, production operations and artificial lift, reservoir engineering, supplemental and enhanced oil recovery, economic evaluation of petroleum projects, environmental and safety issues, and the computer simulation of most of these topics.

The Petroleum Engineering student studies mathematics, computer science, chemistry, physics, general engineering, geology, the humanities, technical communication (including researching subjects, report writing, oral presentations, and listening skills), and environmental topics. A unique aspect is the breadth and depth of the total program structured in a manner that prepares each graduate for a successful career from the standpoints of technical competence, managerial abilities, and multidisciplinary experiences. The needs for continued learning and professionalism are stressed.

The strength of the program comes from the high quality of students and professors. The faculty has expertise in teaching and research in all the major areas of petroleum engineering listed above. Additionally, many of the faculty members have significant industrial backgrounds that lead to meaningful design experiences for the students. Engineering design is taught throughout the curriculum including a senior design course on applying the learned skills to real world reservoir development and management problems.

The department is constantly updating the instructional facilities and equipment for laboratory instruction and experimental research. To maintain leadership in future petroleum engineering technology, decision making, and management, computers are incorporated into every part of the program, from undergraduate instruction through graduate student and faculty research.

The department is close to oil and gas field operations, petroleum companies, research laboratories, and geologic out-crops of nearby producing formations. There are many opportunities for short field trips and for summer and part-time employment in the oil and gas industry.

Degree Requirements (Petroleum Engineering)

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
PHGN100	PHYSICS I - MECHANICS			4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1) or 125			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
CEEN241	STATICS			3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
PEGN201	PETROLEUM ENGINEERING FUNDAMENTALS			3.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				17.0
Spring		**lec**	**lab**	**sem.hrs**
PEGN251	FLUID MECHANICS			3.0
PEGN308	RESERVOIR ROCK PROPERTIES			3.0
PEGN282	PROFESSIONAL SKILLS 1			1.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
HASS200	GLOBAL STUDIES			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
PEGN315	SUMMER FIELD SESSION I	1.0		1.0
				1.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
PEGN311	DRILLING ENGINEERING			3.0

		lec	lab	sem.hrs
PEGN312	PROPERTIES OF PETROLEUM ENGINEERING FLUIDS			3.0
PEGN382	PROFESSIONAL SKILLS 2			1.0
GEOL315	SEDIMENTOLOGY AND STRATIGRAPHY			3.0
CEEN311	MECHANICS OF MATERIALS			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
PEGN361	COMPLETION ENGINEERING			3.0
PEGN411	MECHANICS OF PETROLEUM PRODUCTION			3.0
PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION			3.0
PEGN438	PETROLEUM DATA ANALYTICS			3.0
PEGN482	PROFESSIONAL SKILLS 3			1.0
GEOL308	INTRODUCTORY APPLIED STRUCTURAL GEOLOGY			3.0
S&W	SUCCESS AND WELLNESS			1.0
				17.0
Summer		**lec**	**lab**	**sem.hrs**
PEGN316	SUMMER FIELD SESSION II	2.0		2.0
				2.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
PEGN423	PETROLEUM RESERVOIR ENGINEERING I			3.0
PEGN422	ECONOMICS AND EVALUATION OF OIL AND GAS PROJECTS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective			6.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
PEGN424	PETROLEUM RESERVOIR ENGINEERING II			3.0
PEGN426	FORMATION DAMAGE AND STIMULATION			3.0
PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
				15.0

Total Semester Hrs: 131.0

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- PEGN100 through PEGN599 inclusive

Five-Year Combined Baccalaureate and Master's Degree

The Petroleum Engineering Department offers the opportunity to begin work on a Master of Engineering or Master of Science Degree while completing the requirements for the bachelor's Degree. These degrees are of special interest to those planning on studying abroad or wanting to get a head start on graduate education.

Students enrolled in Mines' combined undergraduate/graduate program may double count up to six credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with "B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

The Petroleum Engineering Department offers the following minor programs:

1. Petroleum Engineering
2. Petroleum Data Analytics

Petroleum Engineering Minor

The PE Department tailors the student's minor to correlate with their interests in the petroleum industry. There are several paths students can take according to their interests. The core set of required courses for a PE minor are as follows:

PEGN201	PETROLEUM ENGINEERING FUNDAMENTALS	3.0
PEGN308	RESERVOIR ROCK PROPERTIES	3.0

The remaining 12 credits can be satisfied by any combination of PEGN courses. Students must consult with the Department to have their sequence of courses approved before embarking on a minor program.

Minor in Petroleum Data Analytics

Program Advisor: Serveh Kamrava

The purpose of this minor is to enhance data analysis skills and to show potential opportunities of data, give students the skill set to manage and analyze the data and use their knowledge of petroleum engineering to make petroleum resource acquisition more economical, safe, and environmentally sound.

Objectives:
By the end of the minor program, students will be able to:

• Collect and pre-process typical petroleum data and to rearrange for use in analysis
• Apply standard probability and statistics methodology to various data constructs
• Analyze data to determine which various regression and prediction techniques would be applicable and to use that analysis process
• To build system algorithms for data information insight
• Use various data analytics analysis and visualization software for the petroleum industry

Minor Requirements

To obtain a Petroleum Data Analytics Minor, students must take a minimum of 18 credits related to Data Analytics. Seven courses (18 credits) are required, which includes one 3-credit course from a list of technical electives. Petroleum Engineering students can use any of their free elective classes and take PEGN438 as part of the normal PEGN credit requirements. See CSM minor requirements here (p. 30). Students should begin their classes for this minor by the fall semester of their junior year in order to graduate in four years.

Prerequisite classes

The following classes are required before the students can take Petroleum Data Analytics Minor:
• MATH112. CALCULUS FOR SCIENTISTS AND ENGINEERS II or

• MATH122. CALCULUS FOR SCIENTISTS AND ENGINEERS II HONORS

• EBGN201. PRINCIPLES OF ECONOMICS

Required Courses (18 credits)

Required Courses		
MATH201	INTRODUCTION TO STATISTICS	3.0
CSCI128	COMPUTER SCIENCE FOR STEM	3.0
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
PEGN440	INTRODUCTION TO THE DIGITAL OILFIELD	3.0
Required PE Major Courses		
PEGN438	PETROLEUM DATA ANALYTICS	3.0
Choose one Technical Elective - All 3-credit courses		
EBGN461	STOCHASTIC MODELS IN MANAGEMENT SCIENCE	3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0

Courses

PEGN198. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN201. PETROLEUM ENGINEERING FUNDAMENTALS. 3.0 Semester Hrs.
This course provides an introduction to the oil and gas industry and the various areas associated with petroleum engineering. Topics covered include exploration, development, drilling, production, stimulation, reservoir management, processing, transportation, engineering ethics and professionalism. This course is required for petroleum engineering majors and is open to those interested in petroleum engineering as a minor, and for any other interested students.
Course Learning Outcomes

- Distinguish the fundamental segments of the petroleum project life cycle: acquisition, exploration, exploitation, development, and abandonment/decommissioning and the oil and gas industry components of upstream, midstream and downstream.
- Distinguish the areas of drilling, completion, production, and reservoir and relate them to each other.
- Practice using petroleum engineering language derived from testing data, engineering drawings, specifications and other technical information.
- Analyze equitable and ethical working conditions for all personnel in the field of petroleum engineering.
- Analyze issues of health, safety, environment, social responsibility, economics, and sustainability as applied to the oil and gas industry.

PEGN251. FLUID MECHANICS. 3.0 Semester Hrs.
Introductory and fundamental course in engineering fluid flow. Properties of fluids and fluid flow, fluid statics, mass and momentum balance, differential equations, dimensional analysis, laminar and turbulent flow in pipes, and two-phase flow. Lecture format with demonstrations and practical problem solving. May not also receive credit for MEGN351 or CEEN310. Prerequisite: CEEN241.
Course Learning Outcomes

- No change

PEGN282. PROFESSIONAL SKILLS 1. 1.0 Semester Hr.
This course is the first in a three-course series designed for petroleum engineering students to develop skills in oral and written communication, professionalism, diversity and ethics. The course is designed as a discussion based seminar course and will focus on critical thinking and problem solving. Assignments will be based on technical and non-technical material relating to earth, energy, and the environment. Students will work individually and in multicultural teams on assignments throughout the semester.
Course Learning Outcomes

- Develop critical thinking skills around topics of earth, energy, and environment
- Demonstrate critical reading skills in field specific research and technical reports
- Work effectively in multicultural teams
- Analyze issues of health, safety, environment, social responsibility and sustainability as applied to the oil and gas industry.

PEGN298. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN305. COMPUTATIONAL METHODS IN PETROLEUM ENGINEERING. 2.0 Semester Hrs.
This course is an introduction to computers and computer programming applied to petroleum engineering. Emphasis will be on learning Visual Basic programming techniques to solve engineering problems. A toolbox of fluid property and numerical techniques will be developed. 2 hours lecture; 2 semester hours. Prerequisite: MATH213.
Course Learning Outcomes

- same

PEGN308. RESERVOIR ROCK PROPERTIES. 3.0 Semester Hrs.
(WI) Introduction to basic reservoir rock properties and their measurements. Topics covered include: porosity, saturations, volumetric equations, land descriptions, trapping mechanism, pressure and temperature gradient, abnormally pressured reservoirs. Darcy's law for linear horizontal and tilted flow, radial flow for single phase liquids and gases, multiphase flow (relative permeability). Capillary pressure and formation compressibility are also discussed. Co-requisites: CEEN241, PEGN251, PEGN201. 2 hours lecture; 3 hours lab; 3 semester hours.
Course Learning Outcomes

- same

PEGN311. DRILLING ENGINEERING. 3.0 Semester Hrs.
Study of drilling operations, rig equipment and procedures, wellbore construction processes and planning, drilling fluid design, hydraulics, well control, bit selection and drill string design, directional drilling, and completion equipment. Prerequisite: PEGN251 with a grade of C or higher, PEGN315, CEEN241. Co-requisite: PEGN305.
Course Learning Outcomes

- same

PEGN312. PROPERTIES OF PETROLEUM ENGINEERING FLUIDS. 3.0 Semester Hrs.
(WI) Properties of fluids encountered in petroleum engineering including reservoir, drilling, and completion fluids, and oilfield waters. Phase behavior, density, viscosity, interfacial tension, and composition of oil, gas, and brine systems. Interpreting lab data for engineering applications. Flash calculations with k-values and equation of state. Introduction to fluid properties software. Laboratory experimentation of fluid properties. Prerequisites: PEGN308 (C or better), CHGN209 (C or better). 2 hours lecture; 3 hours lab; 3 semester hours.
Course Learning Outcomes

- 1. Use the IUPAC rule to name alkane, alkene, alkyne and cycloaliphatic hydrocarbons.
- 2. Use phase diagrams of pure substances and mixtures to calculate physical properties of gases and liquids.
- 3. Use equations of state for ideal and real gases to calculate relationships between volume, pressure and temperature of a gas.
- 4. Describe the five types of reservoir fluids: black oils, volatile oils, retrograde gases, dry gas, and wet gas.
- 5. Use laboratory analysis to identify reservoir fluid type.
- 6. Estimate values of dry and wet gas properties using correlations.
- 7. Describe physical properties of black oils (formation volumes factor, solution gas-oil ratio, total formation volume factor, coefficient of isothermal compressibility, and oil viscosity).
- 8. Identify physical properties of black oils from a reservoir fluid study.
- 9. Apply black oil correlations to determine physical properties.
- 10. Describe properties of oilfield waters
- 11. Analyze the conditions of hydrate formation.
- 12. Conduct and design laboratory experiments related to fluid properties; analyze results and interpret data.

PEGN315. SUMMER FIELD SESSION I. 1.0 Semester Hr.
This 8 day course taken after the completion of the sophomore year is designed to introduce the student to oil and gas field and other engineering operations. Engineering design problems are integrated throughout the 8 day session. On-site visits to various oil field operations in the past included the Rocky Mountain region, the U.S. Gulf Coast, California, Alaska, Canada and Europe. Topics covered include drilling, completions, stimulations, surface facilities, production, artificial lift, reservoir, geology and geophysics. Also included are environmental and safety issues as related to the petroleum industry. 3 hours lab; 1 semester hour. Prerequisite: PEGN308 (grade C or better).
Course Learning Outcomes

- n/a

PEGN316. SUMMER FIELD SESSION II. 2.0 Semester Hrs.
This two week course is taken after the completion of the junior year. Emphasis is placed on the multidisciplinary nature of reservoir management. Field trips in the area provide the opportunity to study eolian, fluvial, lacustrine, near shore, and marine depositional systems. These field trips provide the setting for understanding the complexity of each system in the context of reservoir development and management. Petroleum systems including the source, maturity, and trapping of hydrocarbons are studied in the context of petroleum exploration and development. Geologic methods incorporating both surface and subsurface data are used extensively. 6 hours lab; 2 semester hours. Prerequisite: PEGN315, PEGN419, GEOL308, and GEOL315.
Course Learning Outcomes

- same

PEGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

PEGN350. GEOTHERMAL ENERGY. 3.0 Semester Hrs.
Students will learn geothermal energy resources and their utilization based on geoscience and engineering perspectives. Geoscience topics include world distribution of geothermal resources and their classification, heat and mass transfer, geothermal reservoirs, hydrothermal geochemistry, exploration methods, and resource assessment. Engineering topics include thermodynamics of geothermal fluids, power cycles, electricity generation, drilling and well measurements, reservoir-surface engineering, and direct utilization. Economic and environmental considerations and case studies on social acceptance with community are also presented.

PEGN361. COMPLETION ENGINEERING. 3.0 Semester Hrs.
(WI) This class is a continuation from drilling in PEGN311 into completion operations. Topics include casing design, cement planning, completion techniques and equipment, tubing design, wellhead selection, and sand control, and perforation procedures. 3 hours lecture; 3 semester hours. Prerequisite: PEGN311 and CEEN311.
Course Learning Outcomes

- Unchanged

PEGN382. PROFESSIONAL SKILLS 2. 1.0 Semester Hr.
This course is the second in a three-course series designed for petroleum engineering students to develop skills in oral and written communication, professionalism, diversity and ethics. The course is designed as a discussion based seminar course and will focus on oral and written communication skills. Assignments will be based on technical and non-technical material relating to earth, energy, and the environment. Students will work individually and in multicultural teams on assignments throughout the semester. Prerequisite: PEGN282.
Course Learning Outcomes

- Practice using petroleum engineering language derived from testing data, engineering drawings, specifications and other technical information.
- Write and present technical reports for engineering and management personnel using petroleum engineering terminology.
- Collaborate with multicultural team members to solve operational problems in petroleum engineering.

PEGN398. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN411. MECHANICS OF PETROLEUM PRODUCTION. 3.0 Semester Hrs.
Nodal analysis for pipe and formation deliverability including single and multiphase flow. Natural flow and design of artificial lift methods including gas lift, sucker rod pumps, electrical submersible pumps, and hydraulic pumps. 3 hours lecture; 3 semester hours. Prerequisite: PEGN251, PEGN308 (grade of C or better), PEGN311, and PEGN312.
Course Learning Outcomes

- same

PEGN414. WELL TESTING AND ANALYSIS. 3.0 Semester Hrs.
Solution to the diffusivity equation. Transient well testing: build-up, drawdown, multi-rate test analysis for oil and gas. Flow tests and well deliverabilities. Type curve analysis. Super position, active and interference tests. Well test design. Prerequisites: MATH225 and PEGN419. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- No change

PEGN419. WELL LOG ANALYSIS AND FORMATION EVALUATION. 3.0 Semester Hrs.
Equivalent with GPGN419,
(II) An introduction to well logging methods, including the relationship between measured properties and reservoir properties. Analysis of log suites for reservoir size and content. Graphical and analytical methods will be developed to allow the student to better visualize the reservoir, its contents, and its potential for production. Use of the computer as a tool to handle data, create graphs and log traces, and make computations of reservoir parameters is required. Prerequisites: GEOL315, PHGN 200 (grade of C or better). 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Learn basic petrophysics in open hole logs
- Understand theoretical fundamentals of logs
- Ability to calculate and interpret petrophysical properties
- Ability to interpret well logs

PEGN422. ECONOMICS AND EVALUATION OF OIL AND GAS PROJECTS. 3.0 Semester Hrs.
Project economics for oil and gas projects under conditions of certainty and uncertainty. Topics include time value of money concepts, discount rate assumptions, measures of project profitability, costs, taxes, expected value concept, decision trees, gambler?s ruin, and Monte Carlo simulation techniques. 3 hours lecture; 3 semester hours.

PEGN423. PETROLEUM RESERVOIR ENGINEERING I. 3.0 Semester Hrs.
Data requirements for reservoir engineering studies. Material balance calculations for normal gas, retrograde gas condensate, solution-gas and gas-cap reservoirs with or without water drive. Primary reservoir performance. Forecasting future recoveries by incremental material balance. 3 hours lecture; 3 semester hours. Prerequisite: PEGN419, PEGN316 and MATH 225 or MATH235.
Course Learning Outcomes

- -

PEGN424. PETROLEUM RESERVOIR ENGINEERING II. 3.0 Semester Hrs.
Reservoir engineering aspects of supplemental recovery processes. Introduction to liquid-liquid displacement processes, gas-liquid displacement processes, and thermal recovery processes. Introduction to numerical reservoir simula tion, history matching and forecasting. Prerequisite: PEGN423 and PEGN438. 3 hours lecture; 3 semester hours.

PEGN426. FORMATION DAMAGE AND STIMULATION. 3.0 Semester Hrs.
Skin damage associated with formation damage, well deviation, and perforating. Formation damage mechanisms and causes. Stimulation techniques, including acidizing and fracturing. Calculation of matrix and fracturing rates and pressures. Design of matrix acidizing treatments. Selection/determination of hydraulic fracturing components including rock mechanical properties, in-situ stresses, proppants, fluid types, and diversion. Reservoir considerations in fracture propagation and design. Stimulation diagnostics and their application. Prerequisite: PEGN361 and PEGN411.
Course Learning Outcomes

- unchanged

PEGN428. ADVANCED DRILLING ENGINEERING. 3.0 Semester Hrs.
Rotary drilling systems with emphasis on design of drilling programs, directional and horizontal well planning. This elective course is recommended for petroleum engineering majors interested in drilling. Prerequisite: PEGN311, PEGN361. 3 hours lecture; 3 semester hours.

PEGN430. ENVIRONMENTAL LAW AND SUSTAINABILITY. 3.0 Semester Hrs.
(WI) In this course students will be introduced to the fundamental legal principles that are relevant to sustainable engineering project development. General principles of United States (U.S.) environmental regulation pertaining to air quality, water quality, waste management, hazardous substances remediation, regulation of chemical manufacture and distribution, natural resources, and energy will be discussed in parallel with international laws pertaining to environmental protection and human rights. In the context of engineering project design, students will explore legal, societal, and ethical risks, and risk mitigation methodologies. 3 hours lecture; 3 semester hours. Prerequisites: HASS100. Corequisites: HASS200.
Course Learning Outcomes

- Demonstrate knowledge and understanding, verbally and in writing, of domestic and international environmental law and applicable administrative and judicial procedure.
- Write persuasively and effectively through a variety of formal and informal writing exercises and independent research of environmental law, social responsibility, and sustainability issues.
- Apply knowledge of environmental law, social responsibility, and sustainability in the design and implementation of a team project that promotes just and sustainable engineering solutions.

PEGN438. PETROLEUM DATA ANALYTICS. 3.0 Semester Hrs.
Introduction to elementary probability theory and its applications in engineering and sciences; discrete and continuous probability distributions; parameter estimation; hypothesis testing; linear regression; spatial correlations and geostatistics with emphasis on applications in earth sciences and engineering. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: MATH112 and CSCI128.
Course Learning Outcomes

- unchanged

PEGN439. MULTIDISCIPLINARY PETROLEUM DESIGN. 3.0 Semester Hrs.
Equivalent with GEGN439,GPGN439,
(WI) This is a multi-disciplinary design course that integrates fundamentals and design concepts in geology, geophysics, and petroleum engineering. Students work in integrated teams consisting of students from each of the disciplines. Multiple open-ended design problems in oil and gas exploration and field development, including the development of a prospect in an exploration play and a detailed engineering field study are assigned. Several detailed written and oral presentations are made throughout the semester. Project economics including risk analysis are an integral part of the course. Prerequisites: GEOL308, PEGN316. Co-requisites: PEGN426. 2 hours lecture, 3 hours lab; 3 semester hours.
Course Learning Outcomes

- same

PEGN440. INTRODUCTION TO THE DIGITAL OILFIELD. 3.0 Semester Hrs.
Capstone course for Petroleum Data Analytics minor. The course starts with an introduction to data analysis and visualization packages. The course then has three projects to include drilling, production, and reservoir data analysis along with data visualization techniques. The student will be required to prepare both oral and written and oral project updates and final results. Prerequisite: PEGN438.
Course Learning Outcomes

- Prepare and analyze data from various petroleum data streams including drilling, completions, stimulation, production, and reservoir management.
- Design petroleum engineering projects that satisfy relevant technical, professional, and societal constraints. These projects will incorporate other associated disciplines and will require Use industry analytical graphical software.
- Apply statistical methods to derive insights into petroleum data sets.
- Interpret petroleum data and derive useful conclusions.
- Independent research (prior knowledge, skills attained in previous courses, original ideas, etc.)
- Build a project business plan. Plan will apply project management skills (schedule, budget, tasks, deliverables, resource utilization, internal milestones, Gantt charts, people, and other available tools)
- Demonstrate professionalism through attendance, demeanor, participation, exhibiting integrity, accepting responsibility, taking initiative, team participation and providing leadership as necessary to ensure project success.
- Create formal and informal communications for individual, team, and industry/company use that document and facilitate progress and enhance the impact of the final design.

PEGN450. ENERGY ENGINEERING. 3.0 Semester Hrs.
Energy Engineering is an overview of energy sources that will be available for use in the 21st century. After discussing the history of energy and its contribution to society, we survey the science and technology of energy, including geothermal energy, fossil energy, solar energy, nuclear energy, wind energy, hydro energy, bio energy, energy and the environment, energy and economics, the hydrogen economy, and energy forecasts. This broad background will give you additional flexibility during your career and help you thrive in an energy industry that is evolving from an industry dominated by fossil fuels to an industry working with many energy sources. Prerequisite: MATH213, PHGN200. 3 hours lecture; 3 semester hours.

PEGN460. FLOW IN PIPE NETWORKS. 3.0 Semester Hrs.
This course will provide an introduction to single and two phase hydraulics phenomena and modeling approaches to calculate pressure/temperature profile, losses along and flow rates along a production system. Furthermore, topics related to pipeline flow control and maintenance such as leak detection, damage prevention, integrity and pipe repairs will be covered. Finally, Federal Pipeline Safety Regulations and Health, Safety, and the Environment (HSE) regulations for the transportation of gas and hazardous liquids by pipeline will be discussed. In addition, this course will provide an introduction in transient theoretical modeling and design applications. OLGA transient multiphase flow simulator will be introduced and used to complete homework and final project. Industrial practices and operational problem related to transient production design will be covered. Prerequisites: PEGN251, CHGN209 , MATH225, and PEGN305. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1.Estimate local rates, pressure and temperature drops on individual sections of a given pipeline network for single and two-phase flow system under steady state condition.
- 2. Apply required criteria to select required pipe specifications.
- 3. Establish understanding about flow control and pipeline maintenance.
- 4. Understand HSE regulations to transport gas and hazardous liquids.
- 4.Understand and evaluate different transient flow conditions existing in the oil and natural gas industry.
- 5. Use prediction tools to identify and mitigate transient conditions and flow assurance problems for a given production system.
- 6. Provide solutions to eliminate, mitigate or remediate operational problems in a production system.

PEGN461. SURFACE FACILITIES DESIGN AND OPERATION. 3.0 Semester Hrs.
This course will cover surface facilities typically required in the oil and gas industry. The course provides basic operation, design and evaluation of individual equipment such as Control equipment (control valve, pressure/level/flow rate/temperature), Liquid/gas Separators, Flowmeters, Boosting Equipment (pumps, compressors), Heaters, and Storage. Basic principles are described to design and evaluate different midstream processes such as Oil/water treating, Gas/liquid and liquid/liquid separation, Crude oil stabilization, Gas handling facilities, Dehydration, Gas Sweetening, Liquefied Natural Gas (LNG), Gas to Liquids (GTL). Furthermore, potential operation problems and piping and instrumentation diagram/drawing (P&ID) related to this processes will be discussed. Calculation examples and a design project can be given to integrate all acquired knowledge. Furthermore, ASME and API norms related to material selection, equipment selection, operation and maintenance will be discussed. Finally, Health, Safety, and the Environment (HSE) regulations for midstream operations will be discussed. Course objectives include learning how to select and operate different surface equipment required in the oil and natural gas industry, learning how to monitor, troubleshoot and optimize the operation of different surface equipment required in the oil and natural gas industry. Prerequisites: PEGN251, CHGN209, MATH225, PEGN305. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Select different surface equipment, typically required for oil and natural gas production, treatment and transportation, based on expected operating conditions.
- 2. Monitor, troubleshoot and optimize the operation of different surface equipment required in the oil and natural gas industry.
- 3.Design oil, water and gas handling facilities based on the expected operation requirements.

PEGN462. FLOW ASSURANCE. 3.0 Semester Hrs.
This course will cover hydrocarbon production including design and operational issues. Major subjects to be covered include the prediction of hydrates formation, paraffin, asphaltene, scale and sand deposition, and remedial actions. In addition, operational problems such as slugging, emulsions and corrosion will be covered. This course will provide to student's strong background on hydraulic modeling. Prerequisites: PEGN251, CHGN209, MATH225, and PEGN305. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- The student outcome are the abilities to understand and evaluate different flow assurance problems existing in the oil and natural gas industry. Furthermore, use prediction tools to identify flow assurance problems for a given production system; provide solutions to eliminate, mitigate or remediate flow assurance problems encountered in production systems.

PEGN463. PETROLEUM MIDSTREAM DESIGN. 3.0 Semester Hrs.
This course will cover the development of an integrated project in the midstream area. In this the students will integrate the knowledge from the midstream classes to solve a given problem with consideration of social responsibility and societal impacts. The objective is to work with several companies from the midstream sector to solve field problems. Furthermore, in this class, we will have some classes to cover more specific subjects with different presenters (i.e. safety, regulations, marketing, environment, new technologies for pipe repairs or inspections, software, process to sell/buy oil, etc), field visits, etc. 3 hours lecture; 3 semester hours. Prerequisite: PEGN460, PEGN461, PEGN462. Co-requisite: PEGN460.
Course Learning Outcomes

- TBD

PEGN481. PETROLEUM SEMINAR. 2.0 Semester Hrs.
(I) (WI) Written and oral presentations by each student on current energy topics. This course is designated as a writing intensive course (WI). Prerequisite: none. 2 hours lecture; 2 semester hours.

PEGN482. PROFESSIONAL SKILLS 3. 1.0 Semester Hr.
This course is the third in a three-course series designed for petroleum engineering students to develop skills in oral and written communication, professionalism, diversity and ethics. The course is designed as a discussion based seminar course and will focus on oral and written communication skills, professionalism, diversity and ethics. Assignments will be based on technical and non-technical material relating to earth, energy, and the environment. Students will work individually and in multicultural teams on assignments throughout the semester. Prerequisite: PEGN382.
Course Learning Outcomes

- Adapt communications to various audiences and stakeholders (e.g., managers, community members, regulators, technicians).
- Design equitable and ethical working conditions for all personnel in the field and implement diversity strategies for a common goal.
- Write a professional and/or technical paper or report and present to various stakeholders.

PEGN490. RESERVOIR GEOMECHANICS. 3.0 Semester Hrs.
The course provides an introduction to fundamental rock mechanics and aims to emphasize their role in oil and gas exploration, drilling, completion and production engineering operations. Deformation as a function of stress, elastic moduli, in situ stress, stress magnitude and orientation, pore pressure, strength and fracture gradient, rock characteristic from field data (seismic, logging, drilling, production), integrated wellbore stability analysis, depletion and drilling induced fractures, compaction and associated changes in rock properties, hydraulic fracturing and fracture stability are among the topics to be covered. Pre-requisites: CEEN311. 3 hours lecture; 3 hours lab, 3 semester hours.

PEGN498. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Professors

Hossein Kazemi, Chesebro' Distinguished Chair

Jennifer L. Miskimins, Department Head, F.H. "Mick" Merelli/Cimarex Energy Distinguished Department Head

Erdal Ozkan

Yu-Shu Wu

Associate Professors

Pejman Tahmasebi

Luis E. Zerpa, Associate Department Head, Harry D. Campbell Chair in Petroleum Engineering

Assistant Professors

Parisa Bazazi

Yilin Fan

Serveh Kamrava

Teaching Professor

Linda A. Battalora

Teaching Associate Professors

Mansur Ermila

Mark G. Miller

Research Associate Professors

Omid Moradian

Philip H. Winterfeld

Professor Emeritus

Bill Scoggins, President Emeritus

Craig W. Van Kirk, Professor Emeritus

Ramona M. Graves, Professor and Dean Emeritus

Associate Professor Emeritus

Alfred W. Eustes III, Associate Professor Emeritus

Richard Christiansen, Associate Professor Emeritus

Physics

Program Description – Engineering Physics

Physics provides the foundation for most applied science and engineering disciplines. It attracts those who wish to understand nature at its most fundamental level. The engineering physics program at Mines (https://physics.mines.edu) is interdisciplinary in nature, taking basic undergraduate physics subjects further with direct applications to engineering.

The Bachelor of Science in Engineering Physics is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission’s General Criteria with no applicable program criteria.

At Mines, the required engineering physics curriculum includes the requisite undergraduate physics courses that form rigorous study at any four-year university. In addition to these core courses, Mines requirements include pre-engineering and engineering classes that physics majors at other universities would not ordinarily take. These courses include immersions in engineering science, engineering design, systems, a summer field session practicum, and a capstone senior design sequence culminating in a senior thesis.

The unique blend of physics and engineering makes it possible for a Mines engineering physics graduate to work at the interface between science and technology where new discoveries are made and continually being put into practice. While engineering physicists are proficient applying existing technologies, they are also willing to explore novel approaches and capable of developing new technologies. The excitement and fulfillment of working on innovative challenges make a Mines engineering physics degree attractive to many students.

With the flexibility of our degree, our undergraduates find themselves following a variety of career paths. Many find employment in fields as diverse as aerospace engineering, biomedical science, computational modeling of physical systems, device manufacturing and semiconductor processing, geophysics, materials development, nanotechnology, nuclear science and engineering, renewable and conventional energy industries, semiconductor manufacturing and processing, energy, and even entertainment enterprises that place high demands on animation, audio, special effects, and visualization talents. More than half of our seniors pursue graduate studies in physics or a closely related field of engineering. Some take their undergraduate training into post-graduate professional studies in business, law, management, medicine, or quantum engineering.

Mines physics faculty and staff maintain modern, state-of-the-art laboratories for general physics, modern physics, electronics, and advanced investigations. There are research laboratories for the study of condensed matter, materials science, nuclear physics, optics, and quantum physics and computing. The department maintains well-equipped, professionally staffed, electronic labs and machine shops to help students and faculty accomplish their curriculum, project, and research goals. The department also nurtures strong ties with national laboratories and local engineering design firms that provide students with authentic collaboration opportunities.

Program Educational Objectives (Bachelor of Science in Engineering Physics)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile, the Physics department is dedicated to additional educational objectives.

The program prepares graduates who, based on factual knowledge and other skills necessary to construct an appropriate understanding of physical phenomena in applied contexts, will:

1. Obtain a range of positions in industry or positions in government facilities or pursue graduate education in engineering, science or related fields.
2. Communicate and perform effectively within the criteria of their chosen careers.
3. Engage in appropriate professional societies and continuing education activities.
4. Participate ethically as members of the global society.

Student Learning Outcomes (Bachelor of Science in Engineering Physics)

Each BS Engineering Physics graduate will have:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. an ability to communicate effectively with a range of audiences.
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Program Educational Objectives (Bachelor of Science in Engineering Physics)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile, the Physics department is dedicated to additional educational objectives.

The program prepares graduates who, based on factual knowledge and other skills necessary to construct an appropriate understanding of physical phenomena in applied contexts, will:

1. Obtain a range of positions in industry or positions in government facilities or pursue graduate education in engineering, science or related fields.
2. Communicate and perform effectively within the criteria of their chosen careers.
3. Engage in appropriate professional societies and continuing education activities.
4. Participate ethically as members of the global society.

Student Learning Outcomes (Bachelor of Science in Engineering Physics)

Each BS Engineering Physics graduate will have:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. an ability to communicate effectively with a range of audiences.
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Degree Requirements (Engineering Physics)

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
S&W	SUCCESS AND WELLNESS			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1) or 125			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				15.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0

		lec	lab	sem.hrs
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
EDNS251	CORNERSTONE DESIGN II			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS200	GLOBAL STUDIES			3.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
CSCI250	PYTHON-BASED COMPUTING: BUILDING A SENSOR SYSTEM			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH332	LINEAR ALGEBRA			3.0
PHGN310	HONORS PHYSICS III-MODERN PHYSICS or 300			3.0
PHGN215	ANALOG ELECTRONICS			4.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
PHGN384	FIELD SESSION TECHNIQUES IN PHYSICS			6.0
				6.0

Junior

Fall		**lec**	**lab**	**sem.hrs**
PHGN315	ADVANCED PHYSICS LAB I			2.0
PHGN311	INTRODUCTION TO MATHEMATICAL PHYSICS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
PHGN317	SEMICONDUCTOR CIRCUITS-DIGITAL			3.0
PHGN350	INTERMEDIATE MECHANICS			4.0
				15.0
Spring		**lec**	**lab**	**sem.hrs**
PHGN361	INTERMEDIATE ELECTROMAGNETISM			3.0
PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS			4.0
PHGN326	ADVANCED PHYSICS LAB II			2.0
PHGN341	THERMAL PHYSICS			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
				15.0

Senior

Fall		**lec**	**lab**	**sem.hrs**
PHGN471	SENIOR DESIGN PRINCIPLES I			1.0
PHGN481	SENIOR DESIGN PRACTICE			3.0
PHGN462	ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
FREE	Free Elective I			3.0
FREE	Free Elective II			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
PHGN472	SENIOR DESIGN PRINCIPLES II			1.0
PHGN482	SENIOR DESIGN PRACTICE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
ENG SCI	Engineering Science Elective			3.0
FREE	Free Elective III			3.0
FREE	Free Elective IV			3.0
				16.0

Total Semester Hrs: 130.0

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

PHGN100 through PHGN599 inclusive

Combined Baccalaureate/Master's and Baccalaureate/Doctoral Degree Programs

The Physics Department offers combined BS/MS degree programs in which students obtain an undergraduate degree in Engineering Physics, in as few as four years, as well as a master's degree in Applied Physics, in an Engineering discipline, in Technology Management, in Materials Science, or in Mathematics after an additional year of study. There are engineering tracks, physics tracks, a management track, a materials science track, and a mathematics track. These programs emphasize a strong background in fundamentals of science in addition to practical experience within an applied science, engineering, or mathematics discipline. Many of the undergraduate electives of students involved in each track are specified. For this reason, students are expected to apply to the program during the first semester of their sophomore year (in special cases late entry can be approved by the program mentors). A 3.0 grade-point average must be maintained to guarantee admission into the physics, engineering, and materials science graduate programs. A 3.3

grade-point average must be maintained to guarantee admission into the mathematics graduate program.

Students in the engineering tracks must complete a report or case study during the last year. Students in the physics, materials science, and mathematics tracks must complete a master's thesis. Students in the nuclear engineering program can choose between thesis and non-thesis options. The case study or thesis should begin during the senior year as part of the Senior Design experience. Participants must identify an engineering or physics advisor as appropriate prior to their senior year who will assist in choosing an appropriate project and help coordinate the senior design project with the case study or thesis completed in the last year.

It is also possible for undergraduate students to begin work on a doctoral degree in Applied Physics while completing the requirements for their bachelor's degree. Students in this combined baccalaureate/doctoral program may fulfill part of the requirements of their doctoral degree by including up to 6 hours of specified course credits that are also used to fulfill the requirements of their undergraduate degree. These courses may only be applied toward fulfilling doctoral degree requirements. Courses must meet all requirements for graduate credit, but their grades are not included in calculating the graduate GPA.

Interested students can obtain additional information and detailed curricula from the Physics Department or from the participating engineering departments.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Minor in Engineering Physics

Required Courses - 7.0 credits		
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	4.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
or PHGN310	HONORS PHYSICS III-MODERN PHYSICS	
Elective Courses (select at least 11 credits from the following)		
PHGN215	ANALOG ELECTRONICS	4.0
PHGN315	ADVANCED PHYSICS LAB I	2.0
PHGN317	SEMICONDUCTOR CIRCUITS- DIGITAL	3.0
PHGN324	INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS	3.0
PHGN326	ADVANCED PHYSICS LAB II	2.0
PHGN384	FIELD SESSION TECHNIQUES IN PHYSICS	1-6
PHGN399	INDEPENDENT STUDY	1-6
PHGN417	FUNDAMENTALS OF QUANTUM INFORMATION	3.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0
PHGN422	NUCLEAR PHYSICS	3.0
PHGN424	ASTROPHYSICS	3.0
PHGN433	BIOPHYSICS	3.0
PHGN435	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
PHGN466	MODERN OPTICAL ENGINEERING	3.0

Minor in Physics

Required Courses (16.5 credits)		
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	4.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
or PHGN310	HONORS PHYSICS III-MODERN PHYSICS	
MATH332	LINEAR ALGEBRA	3.0
CSCI250	PYTHON-BASED COMPUTING: BUILDING A SENSOR SYSTEM	3.0
PHGN311	INTRODUCTION TO MATHEMATICAL PHYSICS	3.0
Elective Courses (select at least 2.0 credits from the following)		
PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS	4.0
PHGN341	THERMAL PHYSICS	3.0
PHGN350	INTERMEDIATE MECHANICS	4.0
PHGN361	INTERMEDIATE ELECTROMAGNETISM	3.0
PHGN418	GENERAL RELATIVITY	3.0
PHGN423	PARTICLE PHYSICS	3.0
PHGN440	SOLID STATE PHYSICS	3.0
PHGN450	COMPUTATIONAL PHYSICS	3.0

Courses

PHGN100. PHYSICS I - MECHANICS. 4.0 Semester Hrs.
A first course in physics covering the basic principles of mechanics using vectors and calculus. The course consists of a fundamental treatment of the concepts and applications of kinematics and dynamics of particles and systems of particles, including Newton's laws, energy and momentum, rotation, oscillations, and waves. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1. Prerequisite: MATH111. Co-requisite: MATH112 or MATH122.
Course Learning Outcomes

- No change

PHGN198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN200. PHYSICS II-ELECTROMAGNETISM AND OPTICS. 4.0 Semester Hrs.
Continuation of PHGN100. Introduction to the fundamental laws and concepts of electricity and magnetism, electromagnetic devices, electromagnetic behavior of materials, applications to simple circuits, electromagnetic radiation, and an introduction to optical phenomena. Prerequisite: Grade of C- or higher in PHGN100. Co-requisite: MATH213 or MATH223.

PHGN215. ANALOG ELECTRONICS. 4.0 Semester Hrs.
Introduction to analog devices used in modern electronics and basic topics in electrical engineering. Introduction to methods of electronics measurements, particularly the application of oscilloscopes and computer based data acquisition. Topics covered include circuit analysis, electrical

power, diodes, transistors (FET and BJT), operational amplifiers, filters, transducers, and integrated circuits. Laboratory experiments in the use of basic electronics for physical measurements. Emphasis is on practical knowledge gained in the laboratory, including prototyping, troubleshooting, and laboratory notebook style. 3 hours lecture, 3 hours lab; 4 semester hours. Prerequisite: PHGN200.

PHGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN300. PHYSICS III-MODERN PHYSICS I. 3.0 Semester Hrs.
Equivalent with PHGN310,
Our technical world is filled with countless examples of modern physics. This course will discuss some historic experiments that led to the key discoveries, and the basic concepts, theories, and models behind some of our present day technologies. Topics may include special relativity, quantum physics, atomic and molecular physics, solid-state physics, semiconductor theory and devices, nuclear physics, particle physics and cosmology. 3 hours lecture; 3 semester hours. Prerequisite: PHGN200; Concurrent enrollment in MATH225.

PHGN310. HONORS PHYSICS III-MODERN PHYSICS. 3.0 Semester Hrs.
Equivalent with PHGN300,
The third course in introductory physics with in depth discussion on special relativity, wave-particle duality, the Schroedinger equation, electrons in solids, quantum tunneling, nuclear structure and transmutations. Registration is strongly recommended for declared physics majors and those considering majoring or minoring in physics. 3 hours lecture; 3 semester hours. Prerequisite: PHGN200; Concurrent enrollment in MATH225.

PHGN311. INTRODUCTION TO MATHEMATICAL PHYSICS. 3.0 Semester Hrs.
Demonstration of the unity of diverse topics such as mechanics, quantum mechanics, optics, and electricity and magnetism via the techniques of linear algebra, complex variables, Fourier transforms, and vector calculus. 3 hours lecture; 3 semester hours. Prerequisite: PHGN300 or PHGN310, MATH225, MATH332, and CSCI250.
Course Learning Outcomes

- Given some data, immediately have a set of analysis tools you can use to understand the physics behind it.
- Given a modeling problem, be able to reach into your mathematical toolbox and solve it at least three ways, developing different lines of evidence.
- Given a mathematical technique or idea, be able to understand the deep concepts underlying it and provide a clear physical example.

PHGN315. ADVANCED PHYSICS LAB I. 2.0 Semester Hrs.
(WI) Introduction to laboratory measurement techniques as applied to modern physics experiments. Experiments from optics and atomic physics. A writing-intensive course with laboratory and computer design projects based on applications of modern physics. 1 hour lecture, 3 hours lab; 2 semester hours. Prerequisite: PHGN300/310, PHGN384.

PHGN317. SEMICONDUCTOR CIRCUITS- DIGITAL. 3.0 Semester Hrs.
Introduction to digital devices used in modern electronics. Topics covered include logic gates, flip-flops, timers, counters, multiplexing, analog-to-digital and digital-to-analog devices. Emphasis is on practical circuit design and assembly. Prerequisite: PHGN215 and CSCI250. 2 hours lecture; 3 hours lab; 3 semester hours.
Course Learning Outcomes

- 1. To understand the basics of digital electronics commonly used as part of instrumentation used in physical measurements.
- 2. To be able to construct and recognize combinational and sequential circuits, understand and implement simple state machine design principles in circuit design.
- 3. To be familiar with common techniques, interfaces and tools used in data acquisition.
- 4. Combine these topics to produce a viable microntroller system capable of making physical measurements.

PHGN320. MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS. 4.0 Semester Hrs.
Introduction to the Schroedinger theory of quantum mechanics. Topics include Schroedinger's equation, quantum theory of measurement, the uncertainty principle, eigenfunctions and energy spectra, anular momentum, perturbation theory, and the treatment of identical particles. Example applications taken from atomic, molecular, solid state or nuclear systems. 4 hours lecture; 4 semester hours. Prerequisite: MATH332, MATH342.

PHGN324. INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS. 3.0 Semester Hrs.
Celestial mechanics; Kepler's laws and gravitation; solar system and its contents; electromagnetic radiation and matter; stars: distances, magnitudes, spectral classification, structure, and evolution. Variable and unusual stars, pulsars and neutron stars, supernovae, black holes, and models of the origin and evolution of the universe. 3 hours lecture; 3 semester hours. Prerequisite: PHGN200.
Course Learning Outcomes

- No change

PHGN326. ADVANCED PHYSICS LAB II. 2.0 Semester Hrs.
(WI) Continuation of PHGN315. A writing-intensive course which expands laboratory experiments to include nuclear and solid state physics. 1 hour lecture, 3 hours lab; 2 semester hours. Prerequisite: PHGN315.

PHGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours. Repeatable up to 3 credit hours.

PHGN341. THERMAL PHYSICS. 3.0 Semester Hrs.
An introduction to statistical physics from the quantum mechanical point of view. The microcanonical and canonical ensembles. Heat, work and the laws of thermodynamics. Thermodynamic potentials; Maxwell relations; phase transformations. Elementary kinetic theory. An introduction to quantum statistics. 3 hours lecture; 3 semester hours. Prerequisite: CHGN122 or CHGN125 and PHGN311.
Course Learning Outcomes

- Demonstrate an understanding of the microscopic statistical framework for the thermodynamic properties of systems with a large number of particles

- Demonstrate an understanding of the laws of thermodynamics, their applications, and their justication through statistical physics
- Construct an appropriate understanding of thermodynamic phenomena in an applied context
- Develop communication, teamwork, and leadership skills through group activities

PHGN350. INTERMEDIATE MECHANICS. 4.0 Semester Hrs.
Begins with an intermediate treatment of Newtonian mechanics and continues through an introduction to Hamilton's principle and Hamiltonian and Lagrangian dynamics. Includes systems of particles, linear and driven oscillators, motion under a central force, two-particle collisions and scattering, motion in non-inertial reference frames and dynamics of rigid bodies. 4 hours lecture; 4 semester hours. Prerequisite: PHGN200. Co-requisite: PHGN311.
Course Learning Outcomes

- No change

PHGN361. INTERMEDIATE ELECTROMAGNETISM. 3.0 Semester Hrs.
Theory and application of the following: static electric and magnetic fields in free space, dielectric materials, and magnetic materials; steady currents; scalar and vector potentials; Gauss' law and Laplace's equation applied to boundary value problems; Ampere's and Faraday's laws. 3 hours lecture; 3 semester hours. Prerequisite: PHGN200 and PHGN311.
Course Learning Outcomes

- No change

PHGN384. FIELD SESSION TECHNIQUES IN PHYSICS. 1-6 Semester Hr.
Introduction to the design and fabrication of engineering physics apparatus. Intensive individual participation in the design of machined system components, vacuum systems, electronics, optics, and application of computer interfacing systems and computational tools. Supplementary lectures on safety, laboratory techniques and professional development. Visits to regional research facilities and industrial plants. Prerequisites: PHGN300 or PHGN310, PHGN215, CSCI250. 6 semester hours.
Course Learning Outcomes

- 1. to give students a working knowledge of the practical aspects of materials, instrumentation and phenomena associated with laboratory practice
- 2. to train students in the use of important experimental and data analysis devices and tools
- 3. to show students how working physicists operate and to help them achieve professional standards in work practice and communication

PHGN398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN401. PHYSICS SEMINAR. 1.0 Semester Hr.
Students will attend the weekly physics seminar. Students will be responsible for presentation and discussion. Co-requisite: PHGN300 or PHGN310.

PHGN417. FUNDAMENTALS OF QUANTUM INFORMATION. 3.0 Semester Hrs.
This course serves as a broad introduction to quantum information science, open to students from many backgrounds. The basic structure of quantum mechanics (Hilbert spaces, operators, wavefunctions, entanglement, superposition, time evolution) is presented, as well as a number of important topics relevant to current quantum hardware (including oscillating fields, quantum noise, and more). Finally, we will survey the gate model of quantum computing, and study the critical subroutines which provide the promise of a quantum speedup in future quantum computers. Prerequisite: MATH332 or MATH342.
Course Learning Outcomes

- 1. Construct Hilbert spaces, operators, wavefunctions and predict the outcome of measurements
- 2. Identify the key ways in which quantum mechanics differs from classical mechanics: entanglement and superposition
- 3. Simulate time evolution in quantum systems
- 4. Diagonalize simple quantum Hamiltonians and predict their spectra
- 5. Simulate oscillating fields in quantum systems
- 6. Implement simple calculations using the gate model of quantum computing. They will also learn how to use ancilla qubits, and how to construct arbitrary operations from one- and two-qubit gates
- 7. Identify mechanisms for a quantum speedup in quantum algorithms, learned through a survey of some of the most famous ones

PHGN418. GENERAL RELATIVITY. 3.0 Semester Hrs.
Introduction to Einstein's theory of gravitation. Requisite mathematics introduced and developed including tensor calculus and differential geometry. Formulation of Einstein field and geodesic equations. Development and analysis of solutions including stellar, black hole and cosmological geometries. Prerequisite: PHGN350. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- No change

PHGN419. PRINCIPLES OF SOLAR ENERGY SYSTEMS. 3.0 Semester Hrs.
Review of the solar resource and components of solar irradiance; principles of photovoltaic devices and photovoltaic system design; photovoltaic electrical energy production and cost analysis of photovoltaic systems relative to fossil fuel alternatives; introduction to concentrated photovoltaic systems and manufacturing methods for wafer-based and thin film photovoltaic panels. Prerequisite: PHGN200 and MATH225. 3 hours lecture; 3 semester hours.

PHGN422. NUCLEAR PHYSICS. 3.0 Semester Hrs.
Introduction to subatomic (particle and nuclear) phenomena. Characterization and systematics of particle and nuclear states; symmetries; introduction and systematics of the electromagnetic, weak, and strong interactions; systematics of radioactivity; liquid drop and shell models; nuclear technology. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN423. PARTICLE PHYSICS. 3.0 Semester Hrs.
Introduction to the Standard Model of particle physics including: experimental methods, motivation and evaluation of amplitudes from Feynman diagrams with applications to scattering cross-sections and decay rates, organization of interactions based on underlying gauge-symmetry principles, Dirac equation and relativistic spinors, C, P and T symmetries, renormalization, spontaneous symmetry breaking and the Higgs mechanism for mass generation. Prerequisites: PHGN350. Co-requisites: PHGN320. 3 hour lecture.

PHGN424. ASTROPHYSICS. 3.0 Semester Hrs.
A survey of fundamental aspects of astrophysical phenomena, concentrating on measurements of basic stellar properties such as distance, luminosity, spectral classification, mass, and radii. Simple models of stellar structure evolution and the associated nuclear processes as sources of energy and nucleosynthesis. Introduction to cosmology and physics of standard big-bang models. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN433. BIOPHYSICS. 3.0 Semester Hrs.
Equivalent with PHGN333,
This course is designed to show the application of physics to biology. It will assess the relationships between sequence structure and function in complex biological networks and the interfaces between physics, chemistry, biology and medicine. Topics include: biological membranes, biological mechanics and movement, neural networks, medical imaging basics including optical methods, MRI, isotopic tracers and CT, biomagnetism and pharmacokinetics. Prerequisites: CBEN110. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. To simulate and analyze random biological processes.
- 2. Ability to apply the principles learned in the course to contemporary research topic.
- 3. To understand the concepts of free energy and how it relates to the speed and spontaneity of chemical reactions.
- 4. Ability to work and communicate with others.
- 5. To analyze and solve problems independently.

PHGN435. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 3.0 Semester Hrs.
Equivalent with CBEN435,CBEN535,CHEN435,CHEN535,MLGN535,PHGN535,
Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisite: MATH213 or MATH223.

PHGN440. SOLID STATE PHYSICS. 3.0 Semester Hrs.
An elementary study of the properties of solids including crystalline structure and its determination, lattice vibrations, electrons in metals, and semiconductors. 3 hours lecture; 3 semester hours. Prerequisite: PHGN320.

PHGN441. SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA. 3.0 Semester Hrs.
Continuation of PHGN440/ MLGN502 with an emphasis on applications of the principles of solid state physics to practical properties of materials including: optical properties, superconductivity, dielectric properties, magnetism, noncrystalline structure, and interfaces. (Graduate students in physics may register only for PHGN441.) Prerequisite: PHGN440 or MLGN502. 3 hours lecture; 3 semester hours.

PHGN450. COMPUTATIONAL PHYSICS. 3.0 Semester Hrs.
Introduction to numerical methods for analyzing advanced physics problems. Topics covered include finite element methods, analysis of scaling, efficiency, errors, and stability, as well as a survey of numerical algorithms and packages for analyzing algebraic, differential, and matrix systems. The numerical methods are introduced and developed in the analysis of advanced physics problems taken from classical physics, astrophysics, electromagnetism, solid state, and nuclear physics. Prerequisites: Introductory-level knowledge of C, Fortran, or Basic; and PHGN311. 3 hours lecture; 3 semester hours.

PHGN461. ELEMENTS OF MODERN OPTICS. 3.0 Semester Hrs.
This course is designed to prepare students for a variety of goals including enrollment in advanced optics courses and research in both academia and industry. Topics covered in the course will provide foundational skills vital to all areas of optics and include the use of complex phasor notation, solutions to the wave equation, electromagnetic energy flow, the interaction of electromagnetic energy with matter, light propagation (through lenses, stops, mirrors, prisms, and fiber optics), as well as the effects of polarizers, birefringent materials, and retarders in optical system designs. Prerequisite: PHGN311.
Course Learning Outcomes

- 1. Use complex phasor notation, understand solutions to the Wave Equation, identify what phase is and its relationship with superposition.
- 2. Using basic laws of electricity and magnetism, calculate the direction and magnitude of electromagnetic energy flow including its interaction with matter.
- 3. Form a mathematical description of light propagation.
- 4. Use concepts from light propagation to analyze optical systems containing lenses, stops, mirrors, prisms, and fiber optics.
- 5. Explain the effects polarizers, birefringence, and retarders on light using Jones and Mueller matrix formalism.

PHGN462. ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS. 3.0 Semester Hrs.
Solutions to the electromagnetic wave equation, including plane waves, guided waves, refraction, interference, diffraction and polarization; applications in optics; imaging, lasers, resonators and wave guides. 3 hours lecture; 3 semester hours. Prerequisite: PHGN361.

PHGN466. MODERN OPTICAL ENGINEERING. 3.0 Semester Hrs.
Provides students with a comprehensive working knowledge of optical system design that is sufficient to address optical problems found in their respective disciplines. Topics include paraxial optics, imaging, aberration analysis, use of commercial ray tracing and optimization, diffraction, linear systems and optical transfer functions, detectors and optical system examples.

PHGN471. SENIOR DESIGN PRINCIPLES I. 0.5 Semester Hrs.
(WI) The first of a two semester sequence covering the principles of project design. Class sessions cover effective team organization, project planning, time management, literature research methods, record keeping, fundamentals of technical writing, professional ethics, project funding and intellectual property. Prerequisites: PHGN384 and PHGN326. Co-requisites: PHGN481 or PHGN491. 1 hour lecture in 7 class sessions; 0.5 semester hours.

PHGN472. SENIOR DESIGN PRINCIPLES II. 0.5 Semester Hrs.
(WI) Continuation of PHGN471. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN482 or PHGN492. 1 hour lecture in 7 class sessions; 0.5 semester hours.

PHGN480. LASER PHYSICS. 3.0 Semester Hrs.
Theory and application of the following: Interaction of light with atoms: absorption, gain, rate equations and line broadening. Propagation, control and measurement of light waves: Gaussian beams, optical resonators and wave guides, interferometers. Laser design and operation: pumping, oscillation, and dynamics (Q-switching and mode-locking). Introduction to ultrafast optics. Laboratory: alignment and characterization of laser systems. Prerequisites: PHGN320. Co-requisites: PHGN462. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. understand the interaction of light with quantum transitions, including the origin of gain in different media
- 2. understand how to derive rate equations to describe the balance of stored energy in the gain medium and in the circulating light field in the resonator
- 3. understand how to use matrix methods to calculate the propagation of light as rays and as Gaussian beams and how to use these matrices to design optical resonators
- 4. understand how to build and apply a quantitative model of laser oscillation to a real laser system
- 5. be able to experimentally align and characterize simple lasers and interferometers
- 6. apply the principles of the course to a case study of a laser system

PHGN481. SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.
(WI) The first of a two semester program covering the full spectrum of project design, drawing on all of the student's previous course work. At the beginning of the first semester, the student selects a research project in consultation with the Senior Design Oversight Committee (SDOC) and the Project Mentor. The objectives of the project are given to the student in broad outline form. The student then designs the entire project, including any or all of the following elements as appropriate: literature search, specialized apparatus or algorithms, block-diagram electronics, computer data acquisition and/or analysis, sample materials, and measurement and/or analysis sequences. The course culminates in a formal interim written report. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN471. 6 hour lab; 2.5 semester hours.

PHGN482. SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.
(WI) Continuation of PHGN481. The course culminates in a formal written report and poster. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN472. 6 hour lab; 2.5 semester hours.

PHGN491. HONORS SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.
(WI) Individual work on an advanced research topic that involves more challenging demands than a regular senior design project. Honors students will devote more time to their project, and will produce an intermediate report in a more advanced format. Prerequisite: PHGN384 and PHGN326. Corequisite: PHGN471. 7.5 hour lab; 2.5 semester hours.

PHGN492. HONORS SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.
(WI) Continuation of PHGN481 or PHGN491. The course culminates in a formal written report and poster. The report may be in the form of a manuscript suitable for submission to a professional journal. Prerequisite: PHGN481 or PHGN491. Corequisite: PHGN472. 7.5 hour lab; 2.5 semesterhours.

PHGN498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN498. SPECIAL TOPICS. 1-6 Semester Hr.
This course is designed for anyone interested in teaching physics at either the college or high school level. Topics include teaching methods for class time, recitation, labs, and homework. Students will engage directly with these methods as well as read the literature supporting each. Additionally time will be spent on assessment, both formative and summative; how to probe student thinking, what they are learning each class period, and what they have learned by the end of the term.

PHGN499. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Professors Emeriti

F. Edward Cecil

Reuben T. Collins

Thomas E. Furtak

Frank V. Kowalski

John Scales

P. Craig Taylor

John Trefny, President Emeritus

Don L. Williamson

Associate Professors Emeriti

David M. Wood

Professors

Lincoln D. Carr

Patrice Genevet

Charles G. Durfee III

Uwe Greife

Mark T. Lusk

Frederic Sarazin, Department Head

Jeff A. Squier

Eric. S. Toberer, Director of the Materials Science Program

Lawrence R. Wiencke

Associate Professors

Eliot Kapit

Kyle Leach

Timothy R. Ohno

Meenakshi Singh

Jeramy D. Zimmerman

Assistant Professors

Daniel Adams

Zhexuan Gong

Eric Mayotte

Teaching Professors

Kristine E. Callan

Patrick B. Kohl

H. Vincent Kuo, Associate Department Head, Director of UG Studies

Todd G. Ruskell

Charles A. Stone

Teaching Associate Professor

Emily Smith

Teaching Assistant Professors

Laith Haddad

Alysa (Ly) Malespina

Research Professor

Wendy Adams Spencer

Research Associate Professor

K. Xerxes Steirer

Research Assistant Professors

Serena M. Eley

P. David Flammer

Susanta K. Sarkar

Quantitative Biosciences and Engineering

Degrees Offered:

BS in Quantitative Biosciences and Engineering

Program Requirements

Student admissions to the QBE major will have the same requirements as admissions to Colorado School of Mines. There will be no additional requirements.

Program Description

The undergraduate program in Quantitative Biosciences and Engineering (QBE) is designed to provide a rigorous interdisciplinary training at the interface between biology, mathematics, computer sciences, material sciences, and chemistry, establishing a new hallmark for Colorado School of Mines. The students in the major will complete a program that includes the general Mines core, plus a set of required courses in biological sciences and data sciences along with an approved selection of biology electives. Electives are designed to support students with an interest in particular areas of biology (e.g., medicine, ecology, geobiology, systems biology, or molecular biology) along with critical quantitative and computational skills. Hands-on lab skill development and research opportunities through course-based research, undergraduate research, and independent study credit will be offered in partnership with several Mines research labs and/or corporate internships and co-ops. The curriculum will also focus on the entrepreneurial applications of biological discovery as well as the ethical, societal, and environmental concerns presented by modern biological advances.

QBE Program Level Learning Outcomes

At the end of the QBE curriculum, students should be able to:

1. Explain and apply foundational biological concepts in the areas of 1) evolution, 2) structure-function relationships, 3) biological networks and systems, 4) information storage and transfer, and 5) transformations of energy and matter.
2. Explain and apply core skills and concepts in mathematical, physical, and data sciences including basic programming, working with biological datasets, modeling biological processes, and visualizing data
3. Conduct rigorous experimental biological research through hypothesis testing, experimental design, use of research equipment, data collection, data analysis, and written and oral communication of results to diverse audiences.
4. Work in diverse teams using technical expertise, multidisciplinary skills, effective communication, and entrepreneurship to establish goals, plan tasks, and solve problems.
5. Evaluate the ethical and cultural impacts of modern biology and data science on local communities, worldwide society, and the environment.
6. Obtain a position in quantitative biosciences in industry, government, or graduate/professional school.

Admission Requirements

Student admissions to the QBE major will have the same requirements as admissions to Colorado School of Mines. There will be no additional requirements.

Program Faculty

Joel Bach, Associate Professor of Mechanical Engineering

Linda Battalora, Teaching Professor of Petroleum Engineering

Suzannah Beeler, Assistant Teaching Professor of Chemical and Biological Engineering

Cecilia Diniz Behn, Associate Professor of Applied Mathematics & Statistics

Nanette Boyle, Associate Professor of Chemical and Biological Engineering

Kevin Cash, Assistant Professor of Chemical and Biological Engineering

Anuj Chauhan, Professor of Chemical and Biological Engineering

Kristine Csavina, Teaching Professor of Mechanical Engineering

Dylan Domaille, Assistant Professor of Chemistry

Alina Handorean, Teaching Professor of Engineering, Design & Society

Christopher Higgins, Professor of Civil and Environmental Engineering

Melissa Krebs, Co-Director, QBE Graduate Program and Associate Professor of Chemical and Biological Engineering

Ramya Kumar, Assistant Professor of Chemical and Biological Engineering

Karin Leiderman, Co-Director, QBE Graduate Program and Associate Professor of Applied Mathematics & Statistics

Terry Lowe, Research Professor of Materials and Metallurgical Engineering

David Marr, Professor of Chemical and Biological Engineering

Christine Morrison, Assistant Professor of Chemistry

Cynthia Norrgran, Teaching Associate Professor of Chemical and Biological Engineering

Alexander Pak, Assistant Professor, Chemical and Biological Engineering

Steve Pankavich, Associate Professor of Applied Mathematics & Statistics

Anthony Petrella, Associate Professor of Mechanical Engineering

Andrew Petruska, Assistant Professor of Mechanical Engineering

Matthew Posewitz, Professor of Chemistry

Josh Ramey, Director of the QBE Undergraduate Program and Teaching Associate Professor of Chemical and Biological Engineering

James Ranville, Professor of Chemistry

Susanta Sarkar, Assistant Professor of Physics

Justin Shaffer, Teaching Associate Professor of Chemical and Biological Engineering

Jonathan Sharp, Associate Professor of Civil and Environmental Engineering

Anne Silverman, Associate Professor of Mechanical Engineering

E. Dendy Sloan, Emeritus Professor of Chemical and Biological Engineering

John Spear, Professor, Civil and Environmental Engineering

Jeff Squier, Professor of Physics

Amadeu Sum, Professor of Chemical and Biological Engineering

Brian Trewyn, Associate Professor of Chemistry

Shubham Vyas, Associate Professor of Chemistry

Hua Wang, Associate Professor of Computer Science

Kim Williams, Professor of Chemistry

Xiaoli Zhang, Associate Professor of Mechanical Engineering

Bachelor of Science in Quantitative Biosciences and Engineering Degree Requirements:

Biology Core Requirements

CBEN110	FUNDAMENTALS OF BIOLOGY I	4.0
CBEN120	FUNDAMENTALS OF BIOLOGY II	4.0
BIOL300	INTRODUCTION TO QUANTITATIVE BIOLOGY I	3.0
BIOL301	INTRODUCTION TO QUANTITATIVE BIOLOGY II	3.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN321	INTRO TO GENETICS	4.0
CHGN428	BIOCHEMISTRY	3.0
CHGN431	INTRODUCTORY BIOCHEMISTRY LABORATORY	2.0
CHGN462	MICROBIOLOGY	3.0
or CEEN460	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	
BIOL410	ENTREPRENEURSHIP IN BIOTECHNOLOGY SEMINAR	1.0
BIOL415	QUANTITATIVE BIOSCIENCES AND ENGINEERING FIELD SESSION	3.0
CSCI478	INTRODUCTION TO BIOINFORMATICS	3.0

Fundamental Science and General Requirements

MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0
MATH225	DIFFERENTIAL EQUATIONS	3.0
MATH201	INTRODUCTION TO STATISTICS	3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)	4.0
CHGN221	ORGANIC CHEMISTRY I	3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY	1.0
CHGN222	ORGANIC CHEMISTRY II	3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0
EDNS151	CORNERSTONE - DESIGN I	3.0
HASS100	NATURE AND HUMAN VALUES	3.0
HASS200	GLOBAL STUDIES	3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective Courses	
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective Courses	
PHGN100	PHYSICS I - MECHANICS	4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	4.0
S&W	Success and Wellness (4 electives)	
CSCI128	COMPUTER SCIENCE FOR STEM	3.0
CSM101	FRESHMAN SUCCESS SEMINAR	1.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES	1.0

Free electives

9 credits of free electives. These can be used to cover prerequisites if necessary.

Technical Electives available

Technical electives with emphasis on biology-related courses, chosen from the following:

BIOL500	CELL BIOLOGY AND BIOCHEMISTRY	4.0
BIOL501	ADVANCED BIOCHEMISTRY	3.0
BIOL520	SYSTEMS BIOLOGY	3.0
CBEN304	ANATOMY AND PHYSIOLOGY	3.0
CBEN305	ANATOMY AND PHYSIOLOGY LAB	1.0
CBEN310	INTRODUCTION TO BIOMEDICAL ENGINEERING	3.0
CBEN311	INTRODUCTION TO NEUROSCIENCE	3.0
CBEN322	BIOLOGICAL PSYCHOLOGY	3.0
CBEN324	INTRODUCTION TO BREWING SCIENCE	3.0
CBEN411	NEUROSCIENCE, MEMORY, AND LEARNING	3.0
CBEN412	INTRODUCTION TO PHARMACOLOGY	3.0
CBEN413	QUANTITATIVE HUMAN BIOLOGY	3.0
CBEN431	IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS	3.0
CBEN4XX	CAPSTONE	
CEEN461	FUNDAMENTALS OF ECOLOGY	3.0
CHGN311	INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY	3.0
CHGN409	BIOLOGICAL INORGANIC CHEMISTRY	3.0
CHGN429	BIOCHEMISTRY II	3.0
CHGN441	THE CHEMISTRY AND BIOCHEMISTRY OF PHARMACEUTICALS	3.0
CHGN445	CHEMICAL BIOLOGY	3.0
CSCI220	DATA STRUCTURES AND ALGORITHMS	3.0
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING	3.0
MATH332	LINEAR ALGEBRA	3.0
MATH431	MATHEMATICAL BIOLOGY	3.0
MATH472	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
PHGN433	BIOPHYSICS	3.0
BIOL499	INDEPENDENT STUDIES (up to 6 credits)	
INNO444	INNOV8X CREATE	3.0
INNO544	INNOV8X CREATE DSCI	1.0

Free Technical Elective totals 28 credits

Freshman				
Fall		**lec**	**lab**	**sem.hrs**
CBEN110	FUNDAMENTALS OF BIOLOGY I			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
S&W	SUCCESS AND WELLNESS			1.0
CBEN120	FUNDAMENTALS OF BIOLOGY II			4.0
				16.0
Sophomore				
Fall		**lec**	**lab**	**sem.hrs**
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
PHGN100	PHYSICS I - MECHANICS			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
BIOL300	INTRODUCTION TO QUANTITATIVE BIOLOGY I			3.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
				16.0
Junior				
Fall		**lec**	**lab**	**sem.hrs**
CHGN428	BIOCHEMISTRY			3.0
CHGN431	INTRODUCTORY BIOCHEMISTRY LABORATORY			2.0
HASS200	GLOBAL STUDIES			3.0
BIOL301	INTRODUCTION TO QUANTITATIVE BIOLOGY II			3.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY			3.0
TECH	TECH ELECTIVE INTERDISCIPLINARY BIO TECHNICAL ELECTIVE I			3.0
				17.0

Spring		lec	lab	sem.hrs
ELECTIVE	CULTURE AND SOCIETY (CAS) RESTRICTED ELECTIVE I	3.0		3.0
CBEN321	INTRO TO GENETICS			4.0
TECH	TECH ELECTIVE INTERDISCIPLINARY BIO TECHNICAL ELECTIVE II			3.0
TECH	TECH ELECTIVE INTERDISCIPLINARY BIO TECHNICAL ELECTIVE III	3.0		3.0
CHGN462	MICROBIOLOGY or CEEN 460			3.0
				16.0
Summer		**lec**	**lab**	**sem.hrs**
BIOL415	QUANTITATIVE BIOSCIENCES AND ENGINEERING FIELD SESSION			3.0
				3.0
Senior				
Fall		**lec**	**lab**	**sem.hrs**
ELECTIVE	CULTURE AND SOCIETY (CAS) RESTRICTED ELECTIVE II	3.0		3.0
FREE	FREE ELECTIVE I			3.0
TECH	TECH ELECTIVE INTERDISCIPLINARY BIO TECHNICAL ELECTIVE IV			3.0
EBGN321	ENGINEERING ECONOMICS*For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/			3.0
BIOL410	ENTREPRENEURSHIP IN BIOTECHNOLOGY SEMINAR			1.0
CSCI478	INTRODUCTION TO BIOINFORMATICS			3.0
				16.0
Spring		**lec**	**lab**	**sem.hrs**
FREE	FREE ELECTIVE II			3.0
FREE	FREE ELECTIVE III			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) RESTRICTED ELECTIVE III			3.0
TECH	TECH ELECTIVE INTERDISCIPLINARY BIO TECHNICAL ELECTIVE V			3.0
TECH	TECH ELECTIVE INTERDISCIPLINARY BIO TECHNICAL ELECTIVE VI			3.0
				15.0

Total Semester Hrs: 131.0

* Signifies a new course needed for major degree offering.

Additional Programs

Aerospace Studies

Air Force ROTC (AFROTC)

The Department of Aerospace Studies offers programs leading to an officer's commission in the Air Force in conjunction with an undergraduate or graduate degree.

Aerospace science courses are designed to supplement a regular degree program by offering practical leadership and management experience. The Aerospace Studies Program at Colorado School of Mines (MINES) is offered in conjunction with the University of Colorado at Boulder (CUB).

Four-Year Program

The four-year program consists of two phases: the general military course (freshman and sophomore years) and the professional officer course (junior and senior years). This program is designed for incoming freshmen or any student with four years remaining until degree completion. It consists of three parts: the General Military Course (GMC) for lower division (normally freshmen and sophomore) students; the Professional Officer Course (POC) for upper division students (normally juniors and seniors); and Leadership Laboratory (LLAB-attended by all cadets). Completion of a four-week summer training course is required prior to commissioning.

Leadership Lab

All AFROTC cadets must attend Leadership Lab (two hours per week). The laboratory involves a study of Air Force customs and courtesies, drill and ceremonies, career opportunities, and the life and work of an Air Force officer.

General Military Course (GMC)

The basic course covers Air Force history and organization as well as military leadership and management. Laboratory sessions provide the opportunity to apply leadership skills while learning basic military skills. Enrollment in the basic course incurs no military obligation except for Air Force scholarship recipients.

Professional Officer Course (POC)

The advanced course covers military officership, leadership and unit operations, training techniques, military law, and professional ethics, and includes a leadership practicum each semester. A Field Training encampment provides challenging leadership training and is a prerequisite for commissioning. Advanced course students must have completed the basic course and obtain permission from the Professor of Aerospace Studies (PAS) to enroll in the POC.

Three-Year Program

The three-year program consists of the first two years of GMC courses taken concurrently in one year. The student then attends a Field Training encampment, and completes two years of advanced POC courses.

Scholarship Programs

Two-year, three-year, and four-year college scholarships are available to eligible high school seniors who apply before December 1 of their senior year. Scholarship students receive tuition assistance and mandatory laboratory fees, a book allowance, and a monthly stipend. Students interested in the scholarship program should contact the AFROTC Unit Admissions Officer no later than the beginning of the spring semester to apply for the following academic year. A complete listing of all available AFROTC scholarships is available at www.afrotc.com.

Registration and Credits

Air Force ROTC serves as free elective credit in most departments. Elective course credit toward your degree for AFROTC classes will be determined by your individual academic advisor. Students who wish to register for Air Force ROTC classes do so through the normal course registration process at Mines. AFROTC classes begin with the AFGN prefix. For more information about AFROTC, contact the Detachment 105 Air Force ROTC Unit at 303-492-8278, or the department on campus directly at 303-273-3380. The department is located in the Military Science building at 1020 19th Street.

Other AFROTC Programs

Other programs are frequently available based on current Air Force needs. Contact a Detachment 105 representative at 303-492-8278.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Aerospace Studies Minor

Air Force ROTC cadets desiring to receive a minor in Aerospace Studies must complete at least 20 credits of Aerospace Studies courses as follows:

AFGN101	HERITAGE AND VALUES I	1.5
AFGN102	HERITAGE AND VALUES II	1.5
AFGN201	TEAM AND LEADERSHIP FUNDAMENTALS I	1.5
AFGN202	TEAM AND LEADERSHIP FUNDAMENTALS II	1.5
AFGN301	LEADING PEOPLE AND EFFECTIVE COMMUNICATION I	3.5
AFGN302	LEADING PEOPLE AND EFFECTIVE COMMUNICATION II	3.5
AFGN401	NATIONAL SECURITY, LEADERSHIP RESPONSIBILITIES, COMMISSIONING PREPARATION I	3.5
AFGN402	NATIONAL SECURITY, LEADERSHIP RESPONSIBILITIES, COMMISSIONING PREPARATION II	3.5
Total Semester Hrs		**20.0**

Courses

AFGN101. HERITAGE AND VALUES I. 1.5 Semester Hr.
This course provides an introduction to the Air Force, encourages students to pursue an AF career or seek additional information to be better informed about the role of the USAF. The course allows students to examine general aspects of the Department of the Air Force, AF Leadership, Air Force benefits, and opportunities for AF officers. The course also lays the foundation for becoming an Airman by outlining our heritage and values. Weekly Leadership Lab for this course (to be taken in conjunction with AFGN101 and 102) is a weekly laboratory that touches on the topics of Air Force customs and courtesies, health and physical fitness, and drill and ceremonies.

AFGN102. HERITAGE AND VALUES II. 1.5 Semester Hr.
A continuation of AFGN101. This course provides a historical perspective including lessons on war and the US military, AF operations, principles of war, and airpower. This course also provides students with an understanding for the employment of air and space power, from an institutional, doctrinal, and historical perspective. The students are introduced to the Air Force way of life and gain knowledge on what it means to be an Airman. Weekly Leadership Lab for this course (to be taken in conjunction with AFGN101 and 102) is a weekly laboratory that touches on the topics of Air Force customs and courtesies, health and physical fitness, and drill and ceremonies.

AFGN201. TEAM AND LEADERSHIP FUNDAMENTA. 1.5 Semester Hr.
This course is designed to provide a fundamental understanding of both leadership and team building. This course teaches students that there are many layers to leadership, including aspects that are not always obvious. Such things include listening, understanding themselves, being a good follower, and problem solving efficiently. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AFGN201 and 202) provides you with the opportunity to demonstrate fundamental management skills and prepares you for Field Training.

AFGN202. TEAM AND LEADERSHIP FUNDAMENTALS II. 1.5 Semester Hr.
A continuation of AFGN201. This course is designed to discuss different leadership perspectives when completing team building activities and discussing things like conflict management. This course also provides students with the ability of demonstrating their basic verbal and written communication skills. Active cadets will apply these lessons at Field Training, which follows the AFGN200 level. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AFGN201 and 202) provides you with the opportunity to demonstrate fundamental management skills and prepares you for Field Training.

AFGN301. LEADING PEOPLE AND EFFECTIVE COMMUNICATION I. 3.5 Semester Hrs.
This course is designed to build on the leadership fundamentals taught in the AFGN200 level. The cadets will have the opportunity to utilize their skills as they begin a broader leadership role in the detachment. The goal is for cadets and students to have a more in-depth understanding of how to effectively lead people and provide them with the tools to use throughout their detachment leadership roles. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AFGN301 and 302) provides you the opportunity to develop your fundamental management skills while planning and conducting cadet activities.

AFGN302. LEADING PEOPLE AND EFFECTIVE COMMUNICATION II. 3.5 Semester Hrs.
A continuation of AFGN301. This course is designed to help cadets hone their writing and briefing skills. The course continues into advanced skills and ethics training that will prepare them for becoming an officer and a supervisor. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AFGN301 and 302) provides you the opportunity to develop your fundamental management skills while planning and conducting cadet activities.

AFGN401. NATIONAL SECURITY, LEADERSHIP RESPONSIBILITIES, COMMISSIONING PREPARATION I. 3.5 Semester Hrs.
This course is designed to address the basic elements of national security policy and process. The cadet will comprehend the air and space power operations as well as understand selected roles of the military in society and current domestic and international issues affecting the military profession. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AFGN401 and 402) provides you with the opportunity to use your leadership skills in planning and conducting cadet activities. It prepares you for commissioning and entry into the active-duty Air Force.

AFGN402. NATIONAL SECURITY, LEADERSHIP RESPONSIBILITIES, COMMISSIONING PREPARATION II. 3.5 Semester Hrs.
A continuation of AFGN401. This course is designed to prepare cadets for life as a second lieutenant. Cadets should comprehend the responsibility, authority, and functions of an Air Force commander and selected provisions of the military justice system. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AFGN401 and 402) provides you with the opportunity to use your leadership skills in planning and conducting cadet activities. It prepares you for commissioning and entry into the active-duty Air Force.

Military Science

Army ROTC-AROTC

The Department of Military Science offers programs leading to an officer's commission in the active Army, Army Reserve, or National Guard in conjunction with an undergraduate or graduate degree. Military science courses are designed to supplement a regular degree program by offering practical leadership and management experience. The Military Science Program at the Colorado School of Mines (Mines) is offered in conjunction with the University of Colorado at Boulder (CU-B). Students attend classes at the Colorado School of Mines in Golden.

Four-Year Program

The four-year program consists of two phases: the basic course (freshman and sophomore years) and the advanced course (junior and senior years).

Basic course (MS I and MS II)

The basic course offers a 2- or 3-credit course each semester, covering Army history and organization as well as military leadership and management. Laboratory sessions provide the opportunity to apply leadership skills while learning basic military skills. Enrollment in the basic course incurs no military obligation except for Army scholarship recipients.

Advanced course (MS III and MS IV)

The advanced course covers leadership, tactics and unit operations, training techniques, military law, and professional ethics, and includes a leadership practicum each semester. A 33-day Cadet Summer Training at Fort Knox, Kentucky, provides challenging leadership training and is a prerequisite for commissioning. Advanced course students must have completed the basic course and obtain permission from the Professor of Military Science (PMS).

Two-Year Program

The two-year program consists of the advanced course, preceded by attending the Cadet Summer Training at Ft. Knox, Kentucky. Veterans or Active Army Reserve/Army National Guard Soldiers or students who have participated in three years of Junior ROTC or Civil Air Patrol may be eligible to enroll in the advanced course without attendance at basic camp or completion of the basic course. Advanced course students must obtain permission from the Professor of Military Science (PMS) at 303-492-6495.

Scholarship Programs

Three-year and four-year college scholarships are available to eligible high school seniors, who apply before December 1 of their senior year. Competition for two- and three- year scholarships is open to all university students. Scholarship students receive full tuition and mandatory laboratory fees, a book allowance, and an allowance of $300- $500 per month during the academic year. Students interested in the scholarship program should contact the AROTC Enrollment and Scholarship Officer at 303-492-3549 no later than the beginning of the spring semester to apply for the following academic year.

Simultaneous Membership Program

Students currently in the Army Reserves or Army National Guard and entering either the second year of the basic course or the advanced course may participate in the Simultaneous Membership Program (SMP). Students participating in this program will receive $450 to $500 monthly stipend plus their unit pay at the E-5 grade. SMP participants may be eligible for Army Reserve or Army National Guard tuition assistance benefits.

Leadership Laboratories

Leadership labs provide cadets with practical leadership experience and performance-oriented, hands-on instruction outside the classroom. Diagnostic evaluations of cadets in leadership roles are frequently administered. Leadership labs are compulsory for enrolled cadets. Physical training is conducted three times a week with the purpose of developing muscular strength, endurance, and cardio-respiratory endurance.

Veterans

Veterans who have served on active duty or in the Army Reserve/ National Guard are also eligible for the ROTC program. Although veterans are not required to take the Basic Course, they are encouraged to do so. A minimum of 60 credit hours are required prior to enrolling in the Advanced Course.

Registration and Credits

Army ROTC serves as free elective credit in most departments. Elective course credit toward your degree for AROTC classes will be determined by your individual academic advisor. Students who wish to register for Army ROTC classes do so through the normal course registration process at CSM. AROTC classes begin with the MSGN prefix.

For more information about AROTC, contact:

the Army ROTC Enrollment and Scholarship Officer at:
303-492-3549 or 303-492-6495

or the department on campus directly at:
303-273-3380

The department is located in the Military Science building, 1020 19th Street

You can also go to https://rotc.mines.edu/

For information about ROTC at MINES, call 303-273-3398 or 303-273-3380.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Military Science Minor

Army ROTC cadets desiring to receive a minor in Military Science must complete at least 22 credits of Military Science courses as follows:

MSGN103	ADVENTURES IN LEADERSHIP I	2.0
MSGN104	ADVENTURES IN LEADERSHIP II	2.0
MSGN203	METHODS OF LEADERSHIP AND MANAGEMENT I	2.0
MSGN204	METHODS OF LEADERSHIP AND MANAGEMENT II	2.0
MSGN301	MILITARY OPERATIONS AND TRAINING I	3.0
MSGN302	MILITARY OPERATIONS AND TRAINING II	3.0
MSGN303	LEADERSHIP LABORATORY	0.5
MSGN304	LEADERSHIP LABORATORY	0.5
MSGN401	OFFICER LEADERSHIP AND DEVELOPMENT I	3.0
MSGN402	OFFICER LEADERSHIP AND DEVELOPMENT II	3.0
MSGN403	LEADERSHIP LABORATORY	0.5
MSGN404	LEADERSHIP LABORATORY	0.5
Total Semester Hrs		**22.0**

Note: In order to Commission as a 2nd Lieutenant in the US Army, completion of a Military History Course (HASS365) is also required.

Courses

MSGN103. ADVENTURES IN LEADERSHIP I. 2.0 Semester Hrs.
(I) Introduces fundamentals of leadership and the United States Army. Examines its organization, customs, and history as well as its current relevance and purpose. Students also investigate basic leadership and management skills necessary to be successful in both military and civilian settings. Includes fundamentals of Army leadership doctrine, teambuilding concepts, time and stress management, an introduction to cartography and land navigation, marksmanship, briefing techniques, and some basic military tactics. Lab fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours. (Fall).

MSGN104. ADVENTURES IN LEADERSHIP II. 2.0 Semester Hrs.
(II) Continues the investigation of leadership in small organizations. Covers selected topics such as basic troop leading procedures, military first aid and casualty evacuation concepts, creating ethical work climates, an introduction to Army organizations and installations, and a further examination of basic military tactics. Introduces students to effective military writing styles. Lab fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours. (Spring).

MSGN198. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN203. METHODS OF LEADERSHIP AND MANAGEMENT I. 2.0 Semester Hrs.
(I) Comprehensively reviews advanced leadership and management concepts including motivation, attitudes, communication skills, problem solving, human needs and behavior, and leadership self development. Students continue to refine effective written and oral communications skills and to explore topics such as the basic branches of the Army, and officer and NCO duties. Students conduct classroom and practical exercises in small unit light infantry tactics and are prepared to perform as midlevel leaders in the cadet organization. Lab fee: 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours.
Course Learning Outcomes

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MSGN204. METHODS OF LEADERSHIP AND MANAGEMENT II. 2.0 Semester Hrs.
(II) Focuses on leadership and management functions in military and corporate environments. Studies various components of Army leadership doctrine to include the four elements of leadership, leadership principles, risk management and planning theory, the be-know-do framework, and the Army leadership evaluation program. Continue to refine communication skills. Lab fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80hours field training; 2 semester hours. (Spring).

MSGN298. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN301. MILITARY OPERATIONS AND TRAINING I. 3.0 Semester Hrs.
(I) Further explores the theory of managing and leading small military units with an emphasis on practical applications at the squad and platoon levels. Students examine various leadership styles and techniques as they relate to advanced small unit tactics. Familiarizes students with a variety of topics such as cartography, land navigation, field craft, and weapons systems. Involves multiple, evaluated leadership opportunities in field settings and hands-on experience with actual military equipment.

Students are given maximum leadership opportunities in weekly labs. Prerequisite: none. Lab Fee. 3 hours lecture; 3 semester hours. (Fall).

MSGN302. MILITARY OPERATIONS AND TRAINING II. 3.0 Semester Hrs.
(II) Studies theoretical and practical applications of small unit leadership principles. Focuses on managing personnel and resources, the military decision making process, the operations order, and oral communications. Exposes the student to tactical unit leadership in a variety of environments with a focus on preparation for the summer advance camp experience. Prerequisite: none. Lab Fee. 3 hours lecture; 3 semester hours. (Spring).

MSGN303. LEADERSHIP LABORATORY. 0.5 Semester Hrs.
(I) Development of military leadership techniques to include preparation of operation plans, presentation of instruction, and supervision of underclass military cadets. Instruction in military drill, ceremonies, and customs and courtesies of the Army. Must be taken in conjunction with MSGN301. Prerequisite: none. Lab Fee. 2 hours lab, 3 hours PT, 80 hours field training; .5 semester hour. (Fall).

MSGN304. LEADERSHIP LABORATORY. 0.5 Semester Hrs.
(II) Continued development of military leadership techniques with the major emphasis on leading an Infantry Squad. Training is "handson." Practical exercises are used to increase understanding of the principles of leadership learned in MSGN302. Must be taken in conjunction with MSGN302. Prerequisite: none. Lab Fee. 2 hours lab, 3 hours PT, 80 hours field training; .5 semester hour. (Spring).

MSGN398. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN401. OFFICER LEADERSHIP AND DEVELOPMENT I. 3.0 Semester Hrs.
(I) Examines management and leadership concepts and techniques associated with planning and executing military training and operations at company and higher echelons. Includes analyses of professional ethics and values, effective training principles and procedures, subordinate counseling, and effective staff officer briefing techniques. Also investigates other subjects such as counter terrorism, modern peacekeeping missions, and the impact of the information revolution on the art of land warfare. Conducted both in and out of classroom setting and with multiple practical leadership opportunities to organize cadet training and activities. Prerequisite: none. Lab Fee. 3 hours lecture; 3 semester hours. (Fall).

MSGN402. OFFICER LEADERSHIP AND DEVELOPMENT II. 3.0 Semester Hrs.
(II) Continues MSGN401 study of management and leadership concepts and techniques, providing practical leadership experiences in the classroom and during multiple cadet-run activities. Also examines varied topics such as theory and practice of the military justice system, law of war, military-media relations, support mechanisms for soldiers and their families, operational security considerations, and historical case studies in military leadership in the context of 21st century land warfare. Prerequisite: none. Lab Fee. 3 hours lecture; 3 semester hours. (Spring).

MSGN403. LEADERSHIP LABORATORY. 0.5 Semester Hrs.
(I) Continued development of leadership techniques by assignment in the command and staff positions in the Cadet Battalion. Cadets are expected to plan and execute much of the training associated with the day-to-day operations within the cadet battalion. Utilizing the troop leading and management principles learned in previous classes, cadets analyze the problems which the battalion faces, develop strategies, brief recommendations, and execute the approved plan. Prerequisite: none. Lab Fee. 2 hours lab, 3 hours PT, and 80 hours field training; .5 semester hour. (Fall).

MSGN404. LEADERSHIP LABORATORY. 0.5 Semester Hrs.
(II) Continued leadership development by serving in the command and staff positions in the Cadet Battalion. Cadets take a large role in determining the goals and direction of the cadet organization, under supervision of the cadre. Cadets are required to plan and organize cadet outings and much of the training of underclassmen. Lab Fee. Prerequisite: none. Lab Fee. 2 hours lab, 3 hours PT, and 80 hours field training; .5 semester hour. (Spring).

MSGN498. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Athletics

The Department of Physical Education and Athletics offers a four-fold physical education and athletics program which includes:

1. Physical education classes.
2. Intercollegiate athletics.
3. Intramural athletics and club sports.
4. Recreational athletics.

A large number of students use the institution's facilities for recreational purposes, including swimming, tennis, soccer, basketball, volleyball, weightlifting, softball, and racquetball.

Russell H. Volk Gymnasium

A tri-level complex containing a NCAA regulation basketball arena, two racquetball/handball courts, Jack Hancock Wrestling Center, weight training facility, locker space, and offices for the Athletics Department.

Steinhauer Field House

The 35,000-square foot facility provides for the needs of intercollegiate athletics and physical education classes.

Jim Darden Baseball Field

With dugouts, fencing, 10 inning score-board, netted backstop, press-box and lights for night games. Located west of Stermole Soccer Stadium and has seating accommodations for 500 spectators.

Joe Coors, Jr. Softball Field

With dugouts, batting cage, perimeter fencing, sound system and an irrigation system. Located west of Jim Darden Field seating for 200 people.

Alumni Field at Marv Kay Stadium

Opened in 2015, the state-of-the-art Marv Kay Stadium features seating for 4,090, fan-friendly amenities, and lights for night games and practices. The playing field is a synthetic surface.

Korell Athletic Center

Attached to Marv Kay Stadium, the Korell Athletic Center houses weight training and sports medicine facilities for Mines Athletics, as well as locker rooms and coaching staff offices for football, track and field, and cross country. The second floor includes flexible meeting and classroom space.

Student Recreation Center

A three-level, 108,000-square foot facility that features an 8-lane, 25-yard swimming pool with two diving boards and a 14-person hot tub. There are men's and women's locker rooms, a 4,000-square foot climbing wall, a full-service juice bar, an elevated jogging track, a 5,500-square foot fitness area, two multi-purpose rooms, a recreational gym, and an arena that seats 3,000 for varsity athletic contests.

Swenson Intramural Complex

Two fields are available for intramural/recreation sports.

Stermole Track and Field Complex

Nine-lane metric track with all field event components necessary to host NCAA, RMAC sanctioned events. Seating for 800 spectators.

Stermole Soccer Stadium

Synthetic surface which provides a practice and playing venue for men's and women's NCAA soccer. The stadium seats 500 and features a support building with locker rooms, meeting space, and a press box.

Intercollegiate Athletics

The school is a charter member of the Rocky Mountain Athletic Conference (RMAC) and the National Collegiate Athletic Association (NCAA). Sports offered include: football, men’s and women’s basketball, wrestling, men’s and women’s track, men’s and women’s cross country, baseball, men’s golf, men’s and women’s swimming, men’s and women’s soccer, and women’s volleyball and softball. An athlete can register each semester for 1 hour physical activity credit to meet their graduation requirements.

Through a required athletic fee, all full-time students attending Mines become members of the Mines Athletic Association, which financially supports the intercollegiate athletic program. With this fee, each Mines student receives free admission to all home athletic events. The Director of Athletics administers this program.

Intramural and Club Sports

The intramural program features a variety of activities ranging from those offered in the intercollegiate athletic program to more recreational-type activities. They are governed by the Mines Rec. Sports Department. All activities are offered in the following categories: men, women and co-ed.

The club sport program is governed by the Mines Sport Club Council. There are 14 competitive groups currently under this umbrella. Some teams engage in intercollegiate competition at the non-varsity level, some serve as instructional/recreational entities, and some as strictly recreational interest groups. They are funded through ASCSM. Some of the current organizations are Cycling, Ice Hockey, Lacrosse, Men's Rugby, Women's Rugby, Ski Team, Men's Soccer, Women's Soccer, Men's Ultimate Frisbee, Women's Ultimate Frisbee, Men's Volleyball, Women's Volleyball, Water Polo, Bowling and In-Line Hockey.

Faculty & Staff

Please see our staff directory: https://minesathletics.com/staff-directory

University Honors and Scholars Programs

University Honors & Scholars Programs

University Honors and Scholars Programs (UHSP) cultivate a signature student experience beyond the traditional boundaries of the classroom and across learning communities. UHSP's mission is to offer curricular and co-curricular honors and scholars experiences for students seeking opportunities to shape a distinctive undergraduate pathway that will challenge them, help them grow, build connections, and develop adaptability beyond their technical degrees. UHS programs develop the professional and interpersonal skills engineers and scientists need to succeed in their professions and to make an impact in their various communities. By emboldening interdisciplinary collaboration and experiential learning, UHS programs foster critical thinking, leadership, creativity, and innovation. UHSP opportunities are open to all students and include: interdisciplinary honors pathways, immersive co-curricular scholars activities, distinct hands-on, curricular-based research and mentorship, and STEM-Ed teaching.

UHS Programs:

- Thorson First-Year Honors Experience
- Grandey First-Year Honors Experience
- McBride Honors Program in Public Affairs
- Grand Challenges Scholars Program
- Undergraduate Research Scholars
- Teach@Mines
- Nationally Competitive Scholarships

Visit the University Honors and Scholars Programs webpage at https://honors.mines.edu/.

Thorson First-Year Honors Experience

The Thorson First-Year Honors Experience is a unique and collaborative approach to learning that uses real-world problems to introduce students to the roles engineers and scientists play in a fast-changing world. Working closely with some of the best teachers across the humanities, engineering, and sciences, students in the Honors community come to see how the global challenges of the future require innovative and creative thinking.

The curricular component of the Thorson First-Year Honors Experience is a two-semester interdisciplinary course sequence called IDEAS – Innovation and Discovery in Engineering, Arts, and Sciences. In IDEAS, students explore critical and creative thinking, design, and ethical problem solving through a multitude of lenses: they learn to think like an artist, an engineer, a designer, a poet, and a scientist.

The course sequence fulfills core curriculum requirements for all majors by replacing two required core courses (HASS 100 Nature and Human Values and EDNS 151 Design I).

We believe a world of IDEAS is also a world worth exploring, and each year we offer new and different opportunities within and beyond the course. We aspire to provide all our students with the chance to enrich their first year at Mines in unique ways. Through community engagement opportunities, project-based learning, and teamwork, Thorsonites investigate the intersection of art, design, culture, and society. Co-curricular components of the program include local field trips, community events, and opportunities for education outside the classroom. Through all of these curricular and co-curricular experiences and interactions, learning extends beyond the classroom into the lasting friendships that students develop over the course of their first year.

Courses:

HNRS105. INNOVATION AND DISCOVERY IN ENGINEERING, ARTS, AND SCIENCES I. 3 Semester Hrs.

(I) (WI) "Innovation and Discovery in Engineering, Arts, and Sciences" (IDEAS) applies honors pedagogies in a multidisciplinary, integrated environment that highlights the seamless boundaries between science and engineering, design, ethics, and the arts as a path toward making value-informed design decisions. In addition to developing foundational skills in engineering design and problem-solving, students examine place, identity, and community in various contexts as they learn what it means to be an engaged and mindful citizen and professional. IDEAS poses ethical problems and hands-on design challenges from a multitude of lenses. It incorporates experiential learning, team-based projects, and seminar discussions to encourage students to think both critically and creatively about their world. In order to move on to HNRS 115, HNRS 105 must be completed with a C- or better. Students must pass both HNRS 105 and HNRS 115 to meet degree requirements. If students drop either of these courses, they must take both HASS 100 and EDNS 151 or their equivalents in order to graduate. 2 hours studio; 1 hour seminar; 3 semester hours.

HNRS115. INNOVATION AND DISCOVERY IN ENGINEERING, ARTS, AND SCIENCES II. 4 Semester Hrs.

(II) (WI) "Innovation and Discovery in Engineering, Arts, and Sciences" (IDEAS) applies honors pedagogies in a multidisciplinary, integrated environment that highlights the seamless boundaries between science and engineering, design, ethics, and the arts as a path toward making value-informed design decisions. Students examine place, identity, and community in various contexts as they learn what it means to be an engaged and mindful citizen and professional. IDEAS poses ethical problems and hands-on design challenges from a multitude of lenses. It incorporates experiential learning, team-based projects, and seminar discussions to encourage students to think both critically and creatively about their world. Students must pass both HNRS 105 and HNRS 115 to meet degree requirements. If students drop either of these courses, they must take both HASS 100 and EDNS 151 or their equivalents in order to graduate. Prerequisites: HNRS 105. 3 hours studio; 1 hour seminar; 3 semester hours.
Visit the Thorson website: thorson.mines.edu

Grandey First-Year Honors Experience

The Grandey First-Year Honors Experience is an innovative, collaborative, and interdisciplinary way to start building your capabilities to address the world's complex challenges through leadership, communication, ethics, systems thinking, innovation, and design. Some of the best humanities, engineering, and design faculty will be your guides as you focus on the four themes of the National Academy of Engineering’s Grand Challenges Scholars Program: Sustainability, Secure Living, Health, and Joy of Living.

The curricular component of the Grandey First-Year Honors Experience is a two-semester interdisciplinary course sequence called Leadership by Design. This course sequence fulfills core curriculum requirements for all majors by replacing two required core courses (HASS 100 Nature and Human Values and EDNS 151 Cornerstone Design I). Students experience a combination of experiential learning, interdisciplinary projects, seminar discussions, guest speakers, and design sprints as they grow as leaders, designers, communicators, systems thinkers, collaborators, and innovators. Coursework enables students to learn how to design for people, cultivate innovative mindsets, find their own way to lead, build communication abilities, develop professional skills, and think creatively. Learning extends beyond the classroom through experiences such as local field trips, community events and socials, and leadership workshops. Being part of the Grandey community and taking part in these experiences will help students create some lasting friendships that students develop over the course of their first year at Mines. They also move on after their first year with tools to keep growing such as knowing processes for designing for big problems, thinking systematically, asking better questions, working as a team, communicating well in several ways, and cultivating creativity. The Grandey First-Year Honors Experience is a unique and collaborative approach.

Courses:

HNRS 110. LEADERSHIP BY DESIGN I (I) (WI) In the first of two semesters of this honors experience, students participate in a multidisciplinary, integrated, collaborative environment that blends leadership, design, communication, innovation, and ethics in order to build the capabilities needed to lead and address grand challenges. Students will experience a combination of experiential learning, projects, seminar discussions, guest speakers, and design sprints as they spend time gaining foundational knowledge, learning how to think in systems, analyzing grand challenges, communicating “the story” in multiple ways to various audiences, and designing documents, presentations, objects, and exhibitions while developing their portfolio. In order to move on to HNRS 120, HNRS 110 must be completed with a C- or better. If students drop either of these courses, they must take both HASS 100 and EDNS 151 or their equivalents in order to graduate. 2 hours studio; 1 hour seminar; 3 semester hours. Students must pass both HNRS110 and HNRS120 to meet degree requirements.

HNRS 120 – LEADERSHIP BY DESIGN II (II) (WI) In the second of two semesters of this honors experience, students participate in a multidisciplinary, integrated, collaborative environment that blends leadership, design, communication, innovation, and ethics in order to build the capabilities needed to lead and address grand challenges. Students experience a combination of experiential learning, projects, seminar discussions, guest speakers, and design sprints. Students build on the first semester as they advance leadership skills and work to be better designers, creators, thinkers, innovators, and communicators. They will address the questions “What is good design?” “What is good leadership?” “What is innovation?” and “How do I best tell the story?” Students design documents, presentations, and objects. They investigate ways to create impact and value as they pose solutions for grand challenges, and create a portfolio to document their experience to best tell the story of Leadership by Design. Students must pass both HNRS110 and HNRS120 to meet degree requirements. 3 hours studio; 1 hour seminar; 3 semester hours. Prerequisite: C- or better in HNRS110.

Guy T. McBride, Jr. Honors Program in Public Affairs

The McBride Honors Program in Public Affairs offers a 21-credit minor consisting of seminars, courses, and co-curricular activities that provide a select number of students the opportunity to cross the boundaries of their technical expertise into the ethical, cultural, socio-political, and environmental dimensions of human life. Students will develop their skills in communication, critical thinking, and leadership through seminar-style classes that explore diverse aspects of the human experience. The seminars are designed to offer coherent perspectives across the curriculum, allowing for a maximum degree of discussion and debate on complex topics. Themes, approaches, and perspectives from the humanities and the social sciences are integrated with science and engineering perspectives to develop in students habits of thought necessary for a comprehensive understanding of societal and cultural issues that enhance critical thinking, social responsibility, and enlightened leadership.

Please see the Guy T. McBride, Jr. Honors Program in Interdisciplinary Minors for more details about this program.

Visit the McBride webpage at https://mcbride.mines.edu/.

Grand Challenges Scholars Program

The Grand Challenges Scholars Program (GCSP) prepares students to be world changers and impact makers. The GCSP offers a way to combine coursework, extracurricular activities, and experiences that prepare you to address complex socio-technical issues, such as the National Academy of Engineering (NAE) Grand Challenges and the United Nations Sustainable Development Goals, while receiving certification from the NAE and a scholars designation at graduation. As a scholar, you will have the chance to choose your own pathways to gain skills in interdisciplinary thinking, working across diverse cultures, applying engineering and science in the service of others, entrepreneurship, and addressing problems through design, research, and creativity.

Visit the Grand Challenge Scholars Program webpage at https://grandchallenges.mines.edu/.

Undergraduate Research Scholars

Undergraduate Research Scholars (URS) is a valuable resource for all undergraduate students interested in engaging in a research opportunity. URS assists students in all the stages of the research life cycle-from identifying research projects to helping students share their work. A few focus areas of URS include:

Providing enhanced funding opportunities for undergraduate students:

URS awards funding to undergraduate students through three signature programs: FIRST, MURF, and SURF. These opportunities are open to students of all disciplines. First-year Innovation and Research Scholar Training (FIRST) is designed to recruit incoming first-year students and transfer students to participate in research and support them throughout the first and second semesters on campus. FIRST scholars enroll in the 1-credit course HNRS 150: Entering Research in the fall semester. In this course, students will be introduced to various skills needed to be successful when conducting research. These skills include, best practices to finding a research mentor, the roles and responsibilities of a researcher, developing relationships that make for a successful research experience, how to critically read and analyze scientific literature, lab safety, and disseminating research work. FIRST applications open in June, and students can apply through the undergraduate research website.

Mines Undergraduate Research Fellowship (MURF) provides an opportunity for any undergraduate student to work on a research project proposed by a faculty mentor during the fall and spring semesters. Applications open in April, and students can apply through the undergraduate research website.

Summer Undergraduate Research Fellowship (SURF) program at Mines seeks to provide funding for current Mines undergraduate students to participate in concentrated, full-time research under the mentorship of the Mines faculty during the summer semester.

Promoting and recognizing undergraduate research campus-wide:

URS helps showcase and celebrate undergraduate research by providing a platform for students to disseminate their research at the annual Undergraduate Research Symposium held on the Mines campus and the Mines Undergraduate Research Journal, Reuleaux.

Providing professional development and networking opportunities for undergraduate researchers:

URS offers bi-weekly seminars on topics of interest to undergraduate researchers through the Emerging Scholar Seminar Series. In addition, undergraduate students with two or more semesters of research experience can apply to be an Undergraduate Research Ambassador and help guide other students interested in research.

Visit the Undergraduate Research Scholars webpage at https://mines.edu/undergraduate-research/.

Teach@Mines

Teach@Mines offers courses, a Teaching Minor, advising, and information on certification pathways to help you explore and learn more about the teaching profession.

Teach@Mines is tailored specifically to the needs of Mines students and alumni, with nontraditional pathways toward licensure.

We offer courses and a Teaching Minor for students to both try out teaching and to prepare to teach (K-12 or college). A person can start on this path at any point in their Mines career as an undergraduate, graduate student, or as a Mines alumni. The earlier you begin, the more flexibility you have.

Please see the Teach@Mines Interdisciplinary Minor for more details about this program.

Visit the Teach@Mines webpage at https://mines.edu/teacherprep/.

HNRS105. INNOVATION AND DISCOVERY IN ENGINEERING, ARTS, AND SCIENCES I. 3.0 Semester Hrs.

(I) (WI) "Innovation and Discovery in Engineering, Arts, and Sciences" (IDEAS) applies honors pedagogies in a multidisciplinary, integrated environment that highlights the seamless boundaries between science and engineering, design, ethics, and the arts as a path toward making value-informed technical decisions. In addition to developing foundational skills in engineering design and problem-solving, students examine place, identity, citizenship, and community in various contexts as they learn what it means to be an engaged and mindful citizen and professional. IDEAS poses ethical problems and hands-on design challenges from a multitude of lenses. It incorporates experiential learning, team-based projects, and seminar discussions to encourage students to think both critically and creatively about their world. Students must pass both HNRS105 and HNRS 115 to meet degree requirements. If students drop either of these courses, they must take both HASS100 and EDNS151 or their equivalents in order to graduate.

Course Learning Outcomes

- Identify design problems that respond to needs of place, identity, citizen, and community.
- Recognize and utilize multiple perspectives in the problem-definition process.
- Analyze self and community through multidisciplinary techniques.
- Evaluate a place using ethical, environmental, societal, and cultural lenses.
- Utilize observational and ethnographic research methods.
- Engage in design charrettes, writing projects, and rapid prototyping activities that demonstrate user empathy, values-sensitive design, creativity, synthesis, and/or reflection.
- Give and receive feedback during peer review and portfolio development.
- Increase ethical sensitivity and add to ethical judgment.
- Visually communicate ideas through hand sketching.
- Use written, oral, and graphic communication as a means to discover and reconsider ideas through a process of drafting, collaborating, revising, and editing.

HNRS110. LEADERSHIP BY DESIGN I. 3.0 Semester Hrs.

In the first of two semesters of this honors experience, students participate in a multidisciplinary, integrated, collaborative environment that blends leadership, design, communication, innovation, and ethics in order to build the capabilities needed to lead and address grand challenges. Students will experience a combination of experiential learning, projects, seminar discussions, guest speakers, and design sprints as they spend time gaining foundational knowledge, learning how to think in systems, analyzing grand challenges, communicating ?the story? in multiple ways to various audiences, and designing documents, presentations, objects, and exhibitions. Also, students will begin to develop their portfolio to document the story of their time in Leadership by Design. Students must pass both HNRS110 and HNRS120 to meet degree requirements.

Course Learning Outcomes

- Develop your Capabilities and Mindsets through these 10 C's, so that you Grow as a leader, communicator, thinker, designer, maker, innovator, and collaborator

HNRS115. INNOVATION AND DISCOVERY IN ENGINEERING, ARTS, AND SCIENCES II. 4.0 Semester Hrs.

(WI) "Innovation and Discovery in Engineering, Arts, and Sciences" (IDEAS) applies honors pedagogies in a multidisciplinary, integrated environment that highlights the seamless boundaries between science and engineering, design, ethics, and the arts as a path toward making value-informed technical decisions. Students examine place, identity, citizenship, and community in various contexts as they learn what it means to be an engaged and mindful citizen and professional. IDEAS poses ethical problems and hands-on design challenges from a multitude of lenses. It incorporates experiential learning, team-based projects, and seminar discussions to encourage students to think both critically and creatively about their world. Students must pass both HNRS105 and HNRS115 to meet degree requirements. If students drop either of these courses, they must take both HASS100 and EDNS151 or their equivalents in order to graduate. Prerequisite: HNRS105 with a grade of C- or higher.

Course Learning Outcomes

- Model and communicate formalized design ideas through the use of standardized engineering graphics conventions and computer-aided design/solid modeling software.
- Apply the professional techniques of leadership and team membership in the context of project management.
- Research and analyze an engineered or natural system through multidisciplinary techniques.
- Analyze and evaluate the needs, values, and perspectives of human and non-human stakeholders.
- Design solutions through an iterative testing, refining, and feedback process based on bibliographic research, analysis of technical requirements, environmental risks, user empathy, and stakeholder engagement.
- Develop written and oral arguments that meet the needs of varying rhetorical situations.
- Recognize the need for engineering solutions that are responsive to a multicultural and globalized world.
- Apply ethical reasoning in support of an engineering design solution.

HNRS120. LEADERSHIP BY DESIGN II. 3.0 Semester Hrs.

In the second of two semesters of this honors experience, students participate in a multidisciplinary, integrated, collaborative environment that blends leadership, design, communication, innovation, and ethics in order to build the capabilities needed to lead and address grand challenges. Students will experience a combination of experiential learning, projects, seminar discussions, professional development workshops, guest speakers, and design sprints. Students build on the first semester as they build leadership skills and work to be better designers, creators, thinkers, innovators, and communicators. They will address the questions ?What is good design?? ?What is good

leadership?? ?What is innovation?? and ?How do I best tell the story?? Students design documents, presentations, and objects. They investigate ways to create impact and value as they define problems, pose solutions for grand challenges, and create a portfolio to document their experience to best tell the story of their time in Leadership by Design. Students must pass both HNRS110 and HNRS120 to meet degree requirements. Prerequisite: HNRS110 with a grade of C- or better.
Course Learning Outcomes

- Develop your Capabilities and Mindsets through these 10 C's, so that you Grow as a leader, communicator, thinker, designer, maker, innovator, and collaborator

HNRS150. ENTERING RESEARCH. 1.0 Semester Hr.
In this course, students will be introduced to various skills needed to be successful when conducting research. These skills include best practices to finding a research mentor, the roles and responsibilities of a researcher, developing relationships that make for a successful research experience, how to critically read and analyze scientific literature, lab safety, and disseminating research work.
Course Learning Outcomes

- Student Learning Outcomes

HNRS198. SPECIAL TOPICS. 6.0 Semester Hrs.
A Special Topics course will be a pilot course in the UHSP curriculum or will be offered as an enhancement to regularly-scheduled UHSP seminars. Special Topics courses in the UHSP curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS199. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a UHSP student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled UHSP curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS298. SPECIAL TOPICS. 1-6 Semester Hr.
A Special Topics course will be a pilot course in the UHSP curriculum or will be offered as an enhancement to regularly-scheduled UHSP seminars. Special Topics courses in the UHSP curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS299. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a UHSP student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled UHSP curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS305. EXPLORATIONS IN MODERN AMERICA. 3.0 Semester Hrs.
(WI) Honors core course that develops student skills in reading, writing, critical thinking, and oral communication. skills through the exploration of selected topics related to the social, cultural, and political ideas and events that have shaped the development of the modern United States and its role in the world. 3 lecture hours, 3 credit hours. Prerequisite: HASS100 or HNRS105, HNRS115 or HNRS110, HNRS120 or HNRS198A.

HNRS315. EXPLORATIONS IN THE MODERN WORLD. 3.0 Semester Hrs.
(WI) Honors core course that develops student writing skills and critical thinking abilities through the exploration of selected topics related to the social, cultural, and political ideas and developments that have shaped the modern world. 3 lecture hours, 3 credit hours. Prerequisite: HASS100 or HNRS105, HNRS115 or HNRS110, HNRS120 or HNRS198A.

HNRS398. SPECIAL TOPICS IN THE UNIVERSITY HONORS AND SCHOLARS PROGRAM. 1-6 Semester Hr.
A Special Topics course will be a pilot course in the University Honors & Scholars Programs curriculum or will be offered as an enhancement to regularly-scheduled UHSP seminars. Special Topics courses in the UHSP curriculum will not be offered more than twice.

HNRS399. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a UHSP student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled UHSP curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS405. MCBRIDE PRACTICUM. 1-3 Semester Hr.
(I, II) (WI) With approval of the Program, a McBride student may enroll in an individualized study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. This option may be used to pursue an approved foreign study program, service learning program, international internship, undergraduate research project, or other authorized experiential learning program of study. Students must also prepare a faculty-guided major research paper that integrates the experience with the goals, objectives, and focus of the Honors Program in Public Affairs. 1-3 semester hours. Repeatable up to 6 hours.

HNRS425. EXPLORATIONS IN POLITICS, POLICY, AND LEADERSHIP. 3.0 Semester Hrs.
(WI) Study of selected topics related to policy, politics, and/or leadership through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in The Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS430. EXPLORATIONS IN IDEAS, ETHICS, AND RELIGION. 3.0 Semester Hrs.
(WI) Study of selected topics related to ideas, ethics, and/or religion through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS435. EXPLORATIONS IN CULTURE, SOCIETY, AND CREATIVE ARTS. 3.0 Semester Hrs.
(WI) Study of selected topics related to culture, society, and/or the creative arts through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS440. EXPLORATIONS IN INTERNATIONAL STUDIES & GLOBAL AFFAIRS. 3.0 Semester Hrs.
(WI) Study of selected topics related to international studies and/or global affairs through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS445. EXPLORATIONS IN SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.
(WI) Study of selected topics related to the relationships between science, technology, and society through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS450. EXPLORATIONS IN EARTH, ENERGY, AND ENVIRONMENT. 3.0 Semester Hrs.
(WI) Study of selected topics related to earth, energy, and/or the environment through case studies, readings, research, and writing. This course may focus on the human dimensions or broader impacts of science, technology, engineering, or mathematics. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS476. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.
(II) Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student?s learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. Prerequisites: none. 2 hours lecture; 3-4 hours lab; 3.0 semester hours.

HNRS496. PAYNE SCHOLARS PROGRAM. 1.0 Semester Hr.
Mines graduates often go on to become corporate leaders and are responsible for many of the innovations and changes seen across industries. In much the same way, the research done at Mines has far reaching implications for many of the social, economic, and environmental challenges faced around the world. To develop these relationships, and to prepare students for future roles, the Payne Institute partnered with students to develop a public policy community that uses all the School of Mines? resources to be both physical and social engineers of the world around them. One of the most prominent ways we do this is through the Payne Scholars program. This one-credit course helps students perform research, collaborate across campus, and engage with a broad network of international experts on global policy challenges. Students are taught how to write academic papers on the important issues we are facing today, and once the students finish the course, the papers they write can be published as Payne Commentaries on our website. We often sponsor students for internships, or offer student worker positions to continue their work. This often means that they get to be co-authors on peer-reviewed academic papers or help us build world-shaping policy.

HNRS498. SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS. 1-6 Semester Hr.
A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS499. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

MAED262. K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS. 1.0 Semester Hr.
This course is designed to provide Mines students with opportunities to participate in, analyze, and reflect on issues in a mathematics or computer science K-12 school classroom setting. The overall goal is for Mines students to understand who their students are, build relationships, and begin exploring learner development and learner differences. Specifically, the course will focus on developing Mines students? ability to identify and practice basic classroom management, differentiate instruction, ask probing questions, mathematics or computer science content preconceptions, language/activities that promote a growth mindset, and professional language. Furthermore, Mines students will begin exploring the factors that shape school norms and culture. In addition to an on-campus seminar, there is a 25-hour field experience requirement in the student?s assigned partner school.
Course Learning Outcomes

- • identify and provide examples of differentiated instruction.
- • identify and provide examples of formative-assessment techniques used to evaluate what students are thinking during classroom activities
- • articulate the value of reflecting on their practice.
- • explain different levels of questioning and how to ask probing questions as well as provide examples of how to use these types of questioning.
- • articulate reasons for, ways to, and examples of how they built relationships with each and every student in their classroom.
- • articulate and document the mathematics or computer science content specific preconceptions that they observed students demonstrate during the field placement.
- • identify the school policies and practices of their field placement.
- • identify factors that shaped the culture and norms of the school they experienced.
- • communicate effectively, model appropriate use of language (e.g., use of proper grammar, use of professional language, and use of discipline-specific vocabulary), and identify unprofessional language.
- • articulate the critical role of high ethical standards, including a belief in being committed to displaying ethical conduct towards students, performance and the profession, colleagues, and parents and the community.
- • recognize that with quality instruction and hard work, all students are capable of learning science and mathematics; use language, activities and feedback that is consistent with a growth mindset.

MAED405. MATHEMATICAL PRACTICES AND THE SOCIAL CONTEXT OF MATHEMATICS. 3.0 Semester Hrs.
This course provides teacher candidates an opportunity to develop the skills to promote students mathematical identity and their understanding of mathematical practices and processes - mathematics is a community of inquiry-as articulated in the Colorado Academic Standards and Common Core. These skills will be modeled, practiced and mastered in the context of authentic mathematical practices (eg. the formation of the quadratic equation through maximization of orange production). Teacher candidates will engage as learners, reflect as practitioners, and finally develop their own 3-day mini-unit. To promote candidates awareness of the social context of mathematics, candidates will explore the historical development of content and perspectives from diverse cultures. In addition this course will prepare students to be able to communicate effectively in a variety of mediums (written, oral, and digital) as educators about mathematical processes and practices.

Course Learning Outcomes

- nurture development of mathematical processes and practices. They anticipate how students' use of mathematical practices will look and sound within specific grade-band mathematical topics, knowing that over years of experience, their knowledge of students' ways of using mathematical practices will expand to more mathematical topics.
- identify, adapt, or develop lessons that explicitly teach mathematical process and practices demonstrating these as tools use to solve problems and communicate ideas.
- demonstrate that doing mathematics is a sense-making activity that promotes perseverance, problem posing, and problem solving.
- provide examples and connections for students to see that mathematics is a human endeavor that is practice in and out of school, across many facets of life.
- integrate the history of mathematics into content and share contributions from people with different gender and cultural, linguistic, religious, and racial/ethnic backgrounds.
- articulate how mathematics is based on constructed conventions and agreements about the meanings of words and symbols, and these conventions vary; algorithms considered as standard in the United States different from algorithms used in other countries.
- cultivate their students' mathematical identity by helping students realize the usefulness of mathematics by providing connections to students' everyday lives and building their students mathematics self-efficacy by encouraging hard work from every student and demonstrating the belief that every student is capable of learning and using mathematics
- identify and implement practices that draw on students' mathematical, cultural, and linguistic resources/strengths and challenge practices grounded in deficit-based thinking.
- select, adapt, or develop lessons that explicitly engage students the mathematical practices defined in the Colorado Academic Standards and Common Core in mathematics.
- identify, adapt, or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations.
- create a mini-unit (3 days or more) that explicitly teaches some aspect of mathematical practices or the social context of mathematics.
- • clearly articulate their mathematical ideas in writing. o analyze text based on occasion, audience, form and function. o compose one page reflections with an awareness about introductions, conclusions and topic sentences. o articulate the process of and compose with an awareness about the composing process which is an iterative process of formulation, composition and revision. o incorporate and cite correctly all evidence used to support a text's claim/s.
- • clearly articulate their mathematical ideas verbally. o delineate effective characteristics of multi-media presentations. o articulate mathematical practices in a way that secondary students can understand and be motivated to explore these practices. o collaborate with others towards giving and receiving feedback on both oral and written work about teaching mathematics as a community of inquiry.

MAED425. PRE-ALGEBRA AND ALGEBRA TEACHING TECHNIQUES. 3.0 Semester Hrs.

In this course teacher candidates will be exposed to evidence-based instructional practices to support students learning of pre-algebra and algebra and model meaningful learning opportunities, common misconceptions and ways of thinking, and students learning progressions (i.e., content trajectory). The goal of this course is for teacher candidates is to develop an awareness of 1) the common misconceptions and learning progressions associated with pre-algebra and algebra; 2) students learning progressions in pre-algebra and algebra, and 3) evidence-based and meaningful instructional strategies for pre-algebra and algebra. The teacher candidate analyzes conceptual algebra underpinnings, common misconceptions, and students' ways of thinking to create opportunities to learn.

Course Learning Outcomes

- • plan at least the first month of instruction for a middle or high school pre-algebra or algebra course using standards-based lessons experienced in this course.
- • construct and evaluate mathematical conjectures and argument to validate one's own mathematical thinking.
- • identify and develop lessons that are designed to build students knowledge as defined in the Colorado Academic Standards in mathematics and literacy. Candidates will be able to
- • articulate the scope of the above standards related to the content knowledge necessary for teaching 7-12 students.
- • describe mathematical ideas, using every day and mathematical language, in both verbal and written formats.

MAED464. CAPSTONE CURRICULUM DESIGN I. 6-12 Semester Hr.

This course provides Mines students an intensive teaching experience in a K-12 mathematics or computer science classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 100-hour field experience requirement in the students assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed/concurrent 3 credits of SCED 262; completed/concurrent with MAED 405 or MAED 425. Corequisite: Completed/concurrent 3 credits of SCED 262; completed/concurrent with MAED 405 or MAED 425.

Course Learning Outcomes

- • utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- • identify, adapt, or develop lessons using a core set of pedagogical practices that are effective for developing students' meaningful learning of mathematics which include establishing goals, promoting reasoning and problem solving, connecting mathematical representations, meaningful discourse, purposeful questions, procedural fluency based on conceptual understanding, and productive struggle. While planning lessons program completers will also anticipate and attend to students' prior knowledge, problem solving approaches, mathematical practices, dispositions, mathematical identity, and mathematical communication.

- • use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- • identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- • engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- • learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- • provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.
- • reflect on their practice and use this reflection to set goals for further growth.
- • write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E's (engage, explore, explain, elaborate and evaluate) or other learning cycle model, accommodations, formative assessment and subject integration.

MAED465. CAPSTONE CURRICULUM DESIGN II. 6-12 Semester Hr.
This course provides Mines students an intensive teaching experience in a K-12 mathematics or computer science classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 32-hour per credit hour enrolled field experience requirement in the students assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed MAED 464; completed/concurrent with SCED 333, SCED 363, MAED 405, and MAED 425. Corequisite: Completed/concurrent with SCED 333, SCED 363, MAED 405, and MAED 425.
Course Learning Outcomes

- • utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- • identify, adapt, or develop lessons using a core set of pedagogical practices that are effective for developing students' meaningful learning of mathematics or computer science which include establishing goals, promoting reasoning and problem solving, connecting mathematical representations, meaningful discourse, purposeful questions, procedural fluency based on conceptual understanding, and productive struggle. While planning lessons program completers will also anticipate and attend to students' prior knowledge, problem solving approaches, mathematical practices, dispositions, mathematical identity, and mathematical communication.
- • use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- • identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- • engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- • learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- • provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

MAED505. MATHEMATICAL PRACTICES AND THE SOCIAL CONTEXT OF MATHEMATICS. 3.0 Semester Hrs.

n/a.

Course Learning Outcomes

- nurture development of mathematical processes and practices. They anticipate how students' use of mathematical practices will look and sound within specific grade-band mathematical topics, knowing that over years of experience, their knowledge of students' ways of using mathematical practices will expand to more mathematical topics.
- identify, adapt, or develop lessons that explicitly teach mathematical process and practices demonstrating these as tools use to solve problems and communicate ideas.
- demonstrate that doing mathematics is a sense-making activity that promotes perseverance, problem posing, and problem solving.
- provide examples and connections for students to see that mathematics is a human endeavor that is practice in and out of school, across many facets of life.
- integrate the history of mathematics into content and share contributions from people with different gender and cultural, linguistic, religious, and racial/ethnic backgrounds.
- articulate how mathematics is based on constructed conventions and agreements about the meanings of words and symbols, and these conventions vary; algorithms considered as standard in the United States different from algorithms used in other countries.
- cultivate their students' mathematical identity by helping students realize the usefulness of mathematics by providing connections to students' everyday lives and building their students mathematics self-efficacy by encouraging hard work from every student and demonstrating the belief that every student is capable of learning and using mathematics
- identify and implement practices that draw on students' mathematical, cultural, and linguistic resources/strengths and challenge practices grounded in deficit-based thinking.
- select, adapt, or develop lessons that explicitly engage students the mathematical practices defined in the Colorado Academic Standards and Common Core in mathematics.
- identify, adapt, or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations.
- create a mini-unit (3 days or more) that explicitly teaches some aspect of mathematical practices or the social context of mathematics.
- clearly articulate their mathematical ideas in writing. o analyze text based on occasion, audience, form and function. o compose one page reflections with an awareness about introductions, conclusions and topic sentences. o articulate the process of and compose with an awareness about the composing process which is an iterative process of formulation, composition and revision. o incorporate and cite correctly all evidence used to support a text's claim/s.
- clearly articulate their mathematical ideas verbally. o delineate effective characteristics of multi-media presentations. o articulate mathematical practices in a way that secondary students can understand and be motivated to explore these practices. o collaborate with others towards giving and receiving feedback on both oral and written work about teaching mathematics as a community of inquiry.

MAED525. PRE-ALGEBRA AND ALGEBRA TEACHING TECHNIQUES. 3.0 Semester Hrs.

In this course teacher candidates will be exposed to evidence-based instructional practices to support students? learning of pre-algebra and algebra and model meaningful learning opportunities, common misconceptions and ways of thinking, and students? learning progressions (i.e., content trajectory). The goal of this course is for teacher candidates is to develop an awareness of 1) the common misconceptions and learning progressions associated with pre-algebra and algebra; 2) students learning progressions in pre-algebra and algebra, and 3) evidence-based and meaningful instructional strategies for pre-algebra and algebra. The teacher candidate analyzes conceptual algebra underpinnings, common misconceptions, and students' ways of thinking to create opportunities to learn.

Course Learning Outcomes

- plan at least the first month of instruction for a middle or high school pre-algebra or algebra course using standards-based lessons experienced in this course.
- construct and evaluate mathematical conjectures and argument to validate one's own mathematical thinking.
- identify and develop lessons that are designed to build students knowledge as defined in the Colorado Academic Standards in mathematics and literacy. Candidates will be able to articulate the scope of the above standards related to the content knowledge necessary for teaching 7-12 students.
- describe mathematical ideas, using every day and mathematical language, in both verbal and written formats.

MAED562. K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS. 1-3 Semester Hr.

This course is designed to provide Mines students with opportunities to participate in, analyze, and reflect on issues in a mathematics or computer science K-12 school classroom setting. The overall goal is for Mines students to understand who their students are, build relationships, and begin exploring learner development and learner differences. Specifically, the course will focus on developing Mines students? ability to identify and practice basic classroom management, differentiate instruction, ask probing questions, mathematics or computer science content preconceptions, language/activities that promote a growth mindset, and professional language. Furthermore, Mines students will begin exploring the factors that shape school norms and culture. In addition to an on-campus seminar, there is a 25-hour field experience requirement in the student?s assigned partner school.

Course Learning Outcomes

- identify and provide examples of differentiated instruction.
- identify and provide examples of formative-assessment techniques used to evaluate what students are thinking during classroom activities
- articulate the value of reflecting on their practice.
- explain different levels of questioning and how to ask probing questions as well as provide examples of how to use these types of questioning.
- articulate reasons for, ways to, and examples of how they built relationships with each and every student in their classroom.
- articulate and document the mathematics or computer science content specific preconceptions that they observed students demonstrate during the field placement.
- identify the school policies and practices of their field placement.

- identify factors that shaped the culture and norms of the school they experienced.
- communicate effectively, model appropriate use of language (e.g., use of proper grammar, use of professional language, and use of discipline-specific vocabulary), and identify unprofessional language.
- articulate the critical role of high ethical standards, including a belief in being committed to displaying ethical conduct towards students, performance and the profession, colleagues, and parents and the community.
- recognize that with quality instruction and hard work, all students are capable of learning science and mathematics; use language, activities and feedback that is consistent with a growth mindset.

MAED564. CAPSTONE CURRICULUM DESIGN I. 3.0 Semester Hrs.
This course provides Mines students an intensive teaching experience in a K-12 mathematics or computer science classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is an approximately 6 hours per week (100-hours total) field experience requirement in the student?s assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection).. Prerequisites: Completed/concurrent 3 credits of SCED 562; completed/concurrent with MAED 505 or MAED 525. Corequisites: Completed/concurrent 3 credits of SCED 562; completed/concurrent with MAED 505 or MAED 525.
Course Learning Outcomes

- utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- identify, adapt, or develop lessons using a core set of pedagogical practices that are effective for developing students' meaningful learning of mathematics which include establishing goals, promoting reasoning and problem solving, connecting mathematical representations, meaningful discourse, purposeful questions, procedural fluency based on conceptual understanding, and productive struggle. While planning lessons program completers will also anticipate and attend to students' prior knowledge, problem solving approaches, mathematical practices, dispositions, mathematical identity, and mathematical communication.
- use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.
- reflect on their practice and use this reflection to set goals for further growth.
- write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E's (engage, explore, explain, elaborate and evaluate) or other learning cycle model, accommodations, formative assessment and subject integration.

MAED565. CAPSTONE CURRICULUM DESIGN II. 6-12 Semester Hr.
This course provides Mines students an intensive teaching experience in a K-12 mathematics or computer science classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 2 hours per week (32-hours total) per credit hour enrolled field experience requirement in the student?s assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisites: Completed MAED 564; completed/concurrent with SCED 333, SCED 363, MAED 505, and MAED 425. Corequisites: Completed/concurrent with SCED 333, SCED 363, MAED 505, and MAED 425.
Course Learning Outcomes

- utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.

- identify, adapt, or develop lessons using a core set of pedagogical practices that are effective for developing students' meaningful learning of mathematics or computer science which include establishing goals, promoting reasoning and problem solving, connecting mathematical representations, meaningful discourse, purposeful questions, procedural fluency based on conceptual understanding, and productive struggle. While planning lessons program completers will also anticipate and attend to students' prior knowledge, problem solving approaches, mathematical practices, dispositions, mathematical identity, and mathematical communication.
- use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

SCED262. K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS. 1-3 Semester Hr.

This course is designed to provide Mines students with opportunities to participate in, analyze, and reflect on issues in a science K-12 school classroom setting. The overall goal is for Mines students to understand who their students are, build relationships, and begin exploring learner development and learner differences. Specifically, the course will focus on developing Mines students ability to identify and practice basic classroom management, differentiate instruction, ask probing questions, science content preconceptions, language/activities that promote a growth mindset, and professional language. Furthermore, Mines students will begin exploring the factors that shape school norms and culture. In addition to an on-campus seminar, there is a 25-hour field experience requirement in the students assigned partner school.

Course Learning Outcomes

- • identify and provide examples of differentiated instruction.
- • identify and provide examples of formative-assessment techniques used to evaluate what students are thinking during classroom activities
- • articulate the value of reflecting on their practice.
- • explain different levels of questioning and how to ask probing questions as well as provide examples of how to use these types of questioning.
- • articulate reasons for, ways to, and examples of how they built relationships with each and every student in their classroom.
- • articulate and document the science content specific preconceptions that they observed students demonstrate during the field placement.
- • identify the school policies and practices of their field placement.
- • identify factors that shaped the culture and norms of the school they experienced.
- • communicate effectively, model appropriate use of language (e.g., use of proper grammar, use of professional language, and use of discipline-specific vocabulary), and identify unprofessional language.
- • articulate the critical role of high ethical standards, including a belief in being committed to displaying ethical conduct towards students, performance and the profession, colleagues, and parents and the community.
- • recognize that with quality instruction and hard work, all students are capable of learning science and mathematics; use language, activities and feedback that is consistent with a growth mindset.

SCED333. EDUCATIONAL PSYCHOLOGY AND ASSESSMENT. 3.0 Semester Hrs.

An explosive growth in research on how people learn has revealed many ways to improve teaching and catalyze learning at all ages. The purpose of this course is to present this new science of learning so that educators can creatively translate the science into exceptional practice. This course covers field-defining learning theories ranging from behaviorism to cognitive psychology to social psychology and some lesser-known theories exceptionally relevant to practice, such as arousal theory. Together the theories, evidence, and strategies can be combined endlessly to create original and effective learning plans and the means to know if they succeed.

Course Learning Outcomes

- • Describe in general what cognitive science has learned about how the brain works related to the topics of conceptual understanding, memory, motivation, expertise, study skills, sense of inclusion, problem solving, collaboration, and discovery.
- • Analyze various effective teaching practices in math and the sciences and provide examples of how the above topics in cognitive science inform these practices.
- • utilize research based methods of instruction that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, repeatedly alternating solved and unsolved problems, distributed practice, and assessment to boost retention.
- • effectively integrate technology into instructional and assessment strategies, as appropriate to science and mathematical education and the learner including but not limited to the use of a variety of

resources (e.g., manipulative materials, graphing calculators, every-day hands-on materials, probe ware, and computers).

- •Explain the value of embedding disciplinary research into the high school classroom and provide an example in science or math of how this can be done.
- •• Define data driven instruction, brain plasticity, and individual differences.
- • Utilize formative assessment daily to adjust to students’ needs as they are teaching and to determine where instruction can be improved next time.
- • Utilize pre/post-tests as a form of formative assessment on a unit basis to determine change, learning gains, and effect size by group; Then, use the results to modify their future instruction.
- • Use summative assessment to determine student level of mastery
- • Provide accurate information about the teaching profession related to salary, benefits, and teacher satisfaction.
- • Provide evidence for the nations’ science and math teacher shortage and describe some research-based actions that can help change the direction of this trend.
- • continuously improve their knowledge and understanding of the ever-changing knowledge base of both content, and science/ mathematics pedagogy, including approaches for addressing inequities and inclusion for all students in science and math.

SCED363. DYNAMIC TEACHING: MOTIVATION, CLASSROOM MANAGEMENT, AND DIFFERENTIATION OF INSTRUCTION. 3.0 Semester Hrs.
Effective teaching is a dynamic process that requires the instructor to motivate, manage, and vary instruction for all learners in the classroom. The purpose of this course is to prepare future educators to be able to motivate students, manage classroom behavior, and differentiate their instruction so that all students can learn. This course will cover the field-defining theories of motivation, classroom management, and differentiation. Additionally, this course will introduce research-based practices that can be used to create learning environments where students are motivated and given the tools to be successful in their individual learning.
Course Learning Outcomes

- • Describe theories of motivation and how classroom practices connect to those theories.
- • Describe classroom management theories and how practices connect to those theories.
- • Describe how differentiation techniques can be used to assist students with various exceptionalities.
- • Create effective lesson plans that differentiate instruction for students in a classroom.
- • Evaluate learning environments to recognize effective and ineffective motivation, management, and differentiation techniques in practice.
- • cultivate students’ scientific/mathematics identify and confidence in learning science/math by connecting their instruction and content to students’ background, providing ample opportunities for students to experience and reflect on success in learning science/mathematics content and practices, making their instruction and content relevant to students’ lives, and helping students to contextualize the information being taught.
- • use classroom management, motivation, and differentiation practices to plan for and set the conditions of an effective learning environment.
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • demonstrate a commitment to and respect for diversity, while working toward common goals as a community and as a country.

SCED398. SPECIAL TOPICS. 6.0 Semester Hrs.
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

SCED415. SCIENTIFIC PRACTICES VS ENGINEERING DESIGN AND THE NATURE OF SCIENCE. 3.0 Semester Hrs.
The goal of this course is to prepare students to integrate knowledge of scientific and engineering practices into their teaching as articulated in the Colorado Academic Standards and the Next Generation Science Standards, including asking questions, defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, obtaining, evaluating and communicating information. These skills will be modeled, practiced and mastered in the context of science, specifically: 1) earthquakes and waves, 2) mitosis, meiosis, and reproduction, 4) periodic table of the elements, 5) energy conservation, and 6) forces in static equilibrium. In addition this course will prepare students to be able to communicate effectively in a variety of mediums (written, oral, and digital) as educators about scientific and engineering practices.
Course Learning Outcomes

- 1. engage in appropriate scientific practices and support their students in doing the same.
- 2. identify, adapt or develop lessons specifically designed to engage students in scientific and engineering practices, including but not limited to, asking questions (for science) and defining problems (for engineering); analyzing and interpreting data; engaging in argument from evidence; constructing explanations (for science) and designing solutions (for engineering); developing and using models; planning and carrying out investigations; obtaining, evaluating, and communicating information; and using mathematics and computational thinking. o compare and contrast “Scientific Practice” with “Engineering Design” o judge a student’s abilities to do design practices in an informed way. o describe an engineering design cycle and how to apply it to design challenges o define and provide examples of design criteria and design constraints
- 3. effectively instruct students about and model the basic understandings about the nature of science: science as a way of knowing, scientists use a variety of methods, science is based on evidence, science is open to revision, scientists use models, laws, mechanisms, and theories, science assumes order and consistency in natural systems, science is a human endeavor, and science addresses questions about the natural and material world. o articulate how scientific knowledge is acquired in a way that secondary students can comprehend. o describe the practices that brought about at least one major breakthrough in each of the four primary disciplines of science and how this contributed to our modern understanding of science. o analyze differences

in the process of scientific discovery as described in the course text. o formulate a generalization and assess the evidence used to support a generalization or scientific theory. o provide examples that demonstrate the necessity for observations and characterization of patterns to understand the invisible.

- 4. integrate current issues and events related to science, and age-/grade-appropriate controversial topics presented from multiple science perspectives into lessons using an analytical approach without bias.
- 5. select, adapt, or develop lessons that explicitly engage students in scientific and engineering practices defined by the Colorado Academic Standards in science, and the Next Generation Science Standards (NGSS).
- 6. identify, adapt or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations; for example through cross-cutting concepts defined in NGSS.
- 7. illustrate the value of a model in understanding composition and in science.
- 8. create a mini-unit (3 days or more) that explicitly teaches some aspect of scientific or engineering practice.
- 9. clearly articulate their scientific ideas in writing. o analyze text based on occasion, audience, form and function. o compose one page reflections with an awareness about introductions, conclusions and topic sentences. o articulate the process of and compose with an awareness about the composing process which is an iterative process of formulation, composition and revision. o incorporate and cite correctly all evidence used to support a text’s claim/s.
- 10. clearly articulate their scientific ideas verbally. o delineate effective characteristics of multi-media presentations. o articulate scientific practices in a way that secondary students can understand and be motivated to explore these practices. o collaborate with others towards giving and receiving feedback on both oral and written work about teaching science as a way of knowing.

SCED445. PHYSICS AND CHEMISTRY TEACHING TECHNIQUES. 3.0 Semester Hrs.
In this course students will engage as learners of physics and chemistry through evidence-based teaching strategies. After each unit of instruction, students will reflect on the practices used during the unit and why these practices are effective techniques for teaching science. The goal of this course is for teacher candidates to develop an awareness of 1) the common misconceptions and learning progressions associated with physics and chemistry; 2) evidence-based teaching strategies for physics and chemistry; and 3) the importance of and techniques for placing all content within a context that is familiar to and interesting to your specific student body. Students will leave this course with a minimum of a full month of curriculum annotated and ready to deliver to middle or high school physical science and high school physics courses.
Course Learning Outcomes

- • plan at least the first month of instruction for a middle or high school physics or chemistry course using standards-based lessons experienced in this course.
- • identify lessons that are designed to build students knowledge as defined in the Colorado Academic Standards in science, mathematics, and literacy and the Next Generation Science Standards (NGSS),
- • articulate and offer recommendations for addressing the common student preconceptions associated with all of the topics listed above for physical science and physics.
- • integrate content within identified student personal interest to build student engagement and connections to the world around them.
- • utilize Just in Time Teaching to plan lessons that meet students current interests and background knowledge.
- • articulate the scope of the above standards related to the content knowledge necessary for teaching 7-12 students.
- • articulate and engage students in investigation of the major concepts, principles, theories, laws, and interrelationships in science that underlie what they encounter in teaching.

SCED464. CAPSTONE CURRICULUM DESIGN I. 3.0 Semester Hrs.
This course provides Mines students an intensive teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 100-hour field experience requirement in the students assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed/concurrent 3 credits of SCED 262; completed/concurrent with SCED 415 or SCED 445. Co-requisite: Completed/concurrent 3 credits of SCED 262; completed/concurrent with SCED 415 or SCED 445.
Course Learning Outcomes

- • utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- • identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- • use formative-assessment techniques (10 or more) to evaluate students’ thinking during classroom activities and assess students’ progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • create engaging learning environments that are effective for all students by providing access, support, and challenge for every

student as well as differentiating instruction to meet the needs of all students.

- • identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- • engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- • learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- • provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.
- • reflect on their practice and use this reflection to set goals for further growth.
- • write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E's (engage, explore, explain, elaborate and evaluate) or other learning cycle model, accommodations, formative assessment and subject integration.

SCED465. CAPSTONE CURRICULUM DESIGN II. 6-12 Semester Hr.
This course provides Mines students an immersive student teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 32-hour per credit hour enrolled field experience requirement in the students assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a work sample (unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed SCED 464; completed/concurrent with SCED 333, SCED 363, SCED 415, and SCED 445. Corequisites: Completed/concurrent with SCED 333, SCED 363, SCED 415, and SCED 445.
Course Learning Outcomes

- • utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- • identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science or engineering, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- • use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- • identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- • engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- • learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- • provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

SCED515. SCIENTIFIC PRACTICES VS ENGINEERING DESIGN AND THE NATURE OF SCIENTIFIC KNOWLEDGE. 3.0 Semester Hrs.
The goal of this course is to prepare students to integrate knowledge of scientific and engineering practices into their teaching as articulated in the Colorado Academic Standards and the Next Generation Science Standards, including asking questions, defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, obtaining, evaluating and communicating information. These skills will be modeled, practiced and mastered in the context of science, specifically: 1) earthquakes and waves, 2) mitosis, meiosis, and reproduction, 4) periodic table of the elements, 5) energy conservation, and 6) forces in static equilibrium. In addition this course will prepare students to be able to communicate effectively in a variety of mediums (written, oral, and digital) as educators about scientific and engineering practices.
Course Learning Outcomes

- 1. engage in appropriate scientific practices and support their students in doing the same.
- 2. identify, adapt or develop lessons specifically designed to engage students in scientific and engineering practices, including but not

limited to, asking questions (for science) and defining problems (for engineering); analyzing and interpreting data; engaging in argument from evidence; constructing explanations (for science) and designing solutions (for engineering); developing and using models; planning and carrying out investigations; obtaining, evaluating, and communicating information; and using mathematics and computational thinking. o compare and contrast “Scientific Practice” with “Engineering Design” o judge a student’s abilities to do design practices in an informed way. o describe an engineering design cycle and how to apply it to design challenges o define and provide examples of design criteria and design constraints compare and contrast “Scientific Practice” with “Engineering Design”; judge a student’s abilities to do design practices in an informed way; describe an engineering design cycle and how to apply it to design challenges; define and provide examples of design criteria and design constraints

- 3. effectively instruct students about and model the basic understandings about the nature of science: science as a way of knowing, scientists use a variety of methods, science is based on evidence, science is open to revision, scientists use models, laws, mechanisms, and theories, science assumes order and consistency in natural systems, science is a human endeavor, and science addresses questions about the natural and material world. o articulate how scientific knowledge is acquired in a way that secondary students can comprehend. o describe the practices that brought about at least one major breakthrough in each of the four primary disciplines of science and how this contributed to our modern understanding of science. o analyze differences in the process of scientific discovery as described in the course text. o formulate a generalization and assess the evidence used to support a generalization or scientific theory. o provide examples that demonstrate the necessity for observations and characterization of patterns to understand the invisible.
- 4. integrate current issues and events related to science, and age-/grade-appropriate controversial topics presented from multiple science perspectives into lessons using an analytical approach without bias.
- 5. select, adapt, or develop lessons that explicitly engage students in scientific and engineering practices defined by the Colorado Academic Standards in science, and the Next Generation Science Standards (NGSS).
- 6. identify, adapt or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations; for example through cross-cutting concepts defined in NGSS.
- 7. illustrate the value of a model in understanding composition and in science.
- 8. create a mini-unit (3 days or more) that explicitly teaches some aspect of scientific or engineering practice.
- 9. clearly articulate their scientific ideas in writing. o analyze text based on occasion, audience, form and function. o compose one page reflections with an awareness about introductions, conclusions and topic sentences. o articulate the process of and compose with an awareness about the composing process which is an iterative process of formulation, composition and revision. o incorporate and cite correctly all evidence used to support a text’s claims.
- 10. clearly articulate their scientific ideas verbally. o delineate effective characteristics of multi-media presentations. o articulate scientific practices in a way that secondary students can understand and be motivated to explore these practices. o collaborate with others towards giving and receiving feedback on both oral and written work about teaching science as a way of knowing.

SCED533. EDUCATIONAL PSYCHOLOGY AND ASSESSMENT. 3.0 Semester Hrs.

An explosive growth in research on how people learn has revealed many ways to improve teaching and catalyze learning at all ages. The purpose of this course is to present this new science of learning so that educators can creatively translate the science into exceptional practice. This course covers field-defining learning theories ranging from behaviorism to cognitive psychology to social psychology and some lesser-known theories exceptionally relevant to practice, such as arousal theory. Together the theories, evidence, and strategies can be combined endlessly to create original and effective learning plans and the means to know if they succeed.

Course Learning Outcomes

- Describe in general what cognitive science has learned about how the brain works related to the topics of conceptual understanding, memory, motivation, expertise, study skills, sense of inclusion, problem solving, collaboration, and discovery.
- Analyze various effective teaching practices in math and the sciences and provide examples of how the above topics in cognitive science inform these practices.
- utilize research based methods of instruction that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, repeatedly alternating solved and unsolved problems, distributed practice, and assessment to boost retention.
- effectively integrate technology into instructional and assessment strategies, as appropriate to science and mathematical education and the learner including but not limited to the use of a variety of resources (e.g., manipulative materials, graphing calculators, every-day hands-on materials, probe ware, and computers).
- Explain the value of embedding disciplinary research into the high school classroom and provide an example in science or math of how this can be done.
- Define data driven instruction, brain plasticity, and individual differences.
- Utilize formative assessment daily to adjust to students’ needs as they are teaching and to determine where instruction can be improved next time.
- Utilize pre/post-tests as a form of formative assessment on a unit basis to determine change, learning gains, and effect size by group; Then, use the results to modify their future instruction.
- Use summative assessment to determine student level of mastery
- Provide accurate information about the teaching profession related to salary, benefits, and teacher satisfaction.
- Provide evidence for the nations’ science and math teacher shortage and describe some research-based actions that can help change the direction of this trend.
- continuously improve their knowledge and understanding of the ever-changing knowledge base of both content, and science/mathematics pedagogy, including approaches for addressing inequities and inclusion for all students in science and math.

SCED545. PHYSICS AND CHEMISTRY TEACHING TECHNIQUES. 3.0 Semester Hrs.

In this course students will engage as learners of physics and chemistry through evidence-based teaching strategies. After each unit of

instruction, students will reflect on the practices used during the unit and why these practices are effective techniques for teaching science. The goal of this course is for teacher candidates to develop an awareness of 1) the common misconceptions and learning progressions associated with physics and chemistry; 2) evidence-based teaching strategies for physics and chemistry; and 3) the importance of and techniques for placing all content within a context that is familiar to and interesting to your specific student body. Students will leave this course with a minimum of a full month of curriculum annotated and ready to deliver to middle or high school physical science and high school physics courses.
Course Learning Outcomes

- Plan at least the first month of instruction for a middle or high school physics or chemistry course using standards-based lessons experienced in this course.
- Identify lessons that are designed to build students knowledge as defined in the Colorado Academic Standards in science, mathematics, and literacy and the Next Generation Science Standards (NGSS)
- Articulate and offer recommendations for addressing the common student preconceptions associated with all of the topics listed above for physical science and physics.
- Integrate content within identified student personal interest to build student engagement and connections to the world around them.
- Utilize Just in Time Teaching to plan lessons that meet students current interests and background knowledge.
- Articulate the scope of the above standards related to the content knowledge necessary for teaching 7-12 students.
- Articulate and engage students in investigation of the major concepts, principles, theories, laws, and interrelationships in science that underlie what they encounter in teaching.

SCED562. K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS. 1-3 Semester Hr.
This course is designed to provide Mines students with opportunities to participate in, analyze, and reflect on issues in a science K-12 school classroom setting. The overall goal is for Mines students to understand who their students are, build relationships, and begin exploring learner development and learner differences. Specifically, the course will focus on developing Mines students? ability to identify and practice basic classroom management, differentiate instruction, ask probing questions, science content preconceptions, language/activities that promote a growth mindset, and professional language. Furthermore, Mines students will begin exploring the factors that shape school norms and culture. In addition to an on-campus seminar, there is a 25-hour field experience requirement in the student?s assigned partner school.
Course Learning Outcomes

- Identify and provide examples of differentiated instruction.
- Identify and provide examples of formative-assessment techniques used to evaluate what students are thinking during classroom activities
- Articulate the value of reflecting on their practice.
- Explain different levels of questioning and how to ask probing questions as well as provide examples of how to use these types of questioning.
- Articulate reasons for, ways to, and examples of how they built relationships with each and every student in their classroom.
- Articulate and document the science content specific preconceptions that they observed students demonstrate during the field placement.
- Identify the school policies and practices of their field placement.
- Identify factors that shaped the culture and norms of the school they experienced.
- Communicate effectively, model appropriate use of language (e.g., use of proper grammar, use of professional language, and use of discipline-specific vocabulary), and identify unprofessional language.
- Articulate the critical role of high ethical standards, including a belief in being committed to displaying ethical conduct towards students, performance and the profession, colleagues, and parents and the community.
- Recognize that with quality instruction and hard work, all students are capable of learning science and mathematics; use language, activities and feedback that is consistent with a growth mindset.

SCED563. DYNAMIC TEACHING: MOTIVATION, CLASSROOM MANAGEMENT, AND DIFFERENTIATION OF INSTRUCTION. 3.0 Semester Hrs.
Effective teaching is a dynamic process that requires the instructor to motivate, manage, and vary instruction for all learners in the classroom. The purpose of this course is to prepare future educators to be able to motivate students, manage classroom behavior, and differentiate their instruction so that all students can learn. This course will cover the field-defining theories of motivation, classroom management, and differentiation. Additionally, this course will introduce research-based practices that can be used to create learning environments where students are motivated and given the tools to be successful in their individual learning.
Course Learning Outcomes

- Describe theories of motivation and how classroom practices connect to those theories.
- Describe classroom management theories and how practices connect to those theories.
- Describe how differentiation techniques can be used to assist students with various exceptionalities.
- Create effective lesson plans that differentiate instruction for students in a classroom.
- Evaluate learning environments to recognize effective and ineffective motivation, management, and differentiation techniques in practice.
- Cultivate students' scientific/mathematics identify and confidence in learning science/math by connecting their instruction and content to students' background, providing ample opportunities for students to experience and reflect on success in learning science/mathematics content and practices, making their instruction and content relevant to students' lives, and helping students to contextualize the information being taught.
- Use classroom management, motivation, and differentiation practices to plan for and set the conditions of an effective learning environment.
- Apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- Demonstrate a commitment to and respect for diversity, while working toward common goals as a community and as a country.

SCED564. CAPSTONE CURRICULUM DESIGN I. 3.0 Semester Hrs.
This course provides Mines students an intensive teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in

the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is an approximately 6 hours per week (100-hours total) field experience requirement in the student?s assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed/concurrent 3 credits of SCED 562; completed/concurrent with SCED 515 or SCED 545. Co-requisite: Completed/concurrent 3 credits of SCED 562; completed/concurrent with SCED 515 or SCED 545.
Course Learning Outcomes

- Utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- Identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- Use formative-assessment techniques (10 or more) to evaluate students’ thinking during classroom activities and assess students’ progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills
- Apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- Create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- Identify lessons that are well designed to build students’ reading, writing, speaking and listening with science or mathematics classes.
- Engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student’s teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- Learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school’s teachers, administrators, parents, students and community in which it is situated.
- Provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.
- Reflect on their practice and use this reflection to set goals for further growth.
- Write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E’s (engage, explore, explain, elaborate and evaluate) or other learning cycle model, accommodations, formative assessment and subject integration.

SCED565. CAPSTONE CURRICULUM DESIGN II. 6-12 Semester Hr.
This course provides Mines students an immersive student teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 32-hour per credit hour enrolled field experience requirement in the student's assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a work sample (unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisites: Completed SCED 564; completed/concurrent with SCED 333, SCED 363, SCED 515, and SCED 545. Corequisites: Completed/concurrent with SCED 333, SCED 363, SCED 515, and SCED 545.
Course Learning Outcomes

- Utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- Identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science or engineering, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- Use formative-assessment techniques (10 or more) to evaluate students’ thinking during classroom activities and assess students’ progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- Apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).

- Create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- Identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- Engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- Learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- Provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

Executive Director

Toni Lefton, Executive Director, University Honors & Scholars Programs and Assistant Provost for Signature Student Experience, Teaching Professor

Teaching Professors

Carrie "Cj" McClelland, Director Grandey First-Year Honors Experience and Director, Grand Challenges Scholars Program

Melanie Brandt, Director, McBride Honors Program

Teaching Assistant Professor

Lauren Shumaker, Director, Thorson First-Year Honors Experience

Teaching Associate Professors

Harry Archer

Allison Caster

Justin Latici, McBride Practicum Advisor

Research Professor

Wendy Adams, Director, Teach@MInes

Professor of Practice

Christine Liebe

Research Associate

Jia Wern Hue

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Stephan Graham

Charles Powell

Administrative Faculty

Karin Murray, UHS Department Manager

Lakshmi Krishna, Director, Undergraduate Research Scholars

Ashley Weibel, Assistant Director, Undergraduate Research Scholars and Nationally Competitive Scholarships

Administrative Support

Allie Bolter, Teach@Mines Program Coordinator

Kassandra Pontilo, UHS Program Coordinator

Interdisciplinary Minors

Additive Manufacturing

Program Offered

- Minor in Additive Manufacturing

Program Description

The Minor in Additive Manufacturing provides undergraduate students with the practical, interdisciplinary skills to apply cutting-edge manufacturing techniques to a wide range of industries, including aerospace, biomedical, defense, and energy, among others.

This program highlights the process, design, materials, data aspects and operational efficiency aspects of additive manufacturing with an emphasis on additive manufacturing of structural materials and smart manufacturing operations.

Minor and ASI in Additive Manufacturing

The interdisciplinary Additive Manufacturing program will prepare undergraduates to meet the challenges of careers in additive manufacturing. Undergraduate students have the following degree options:

- Area of Special Interest (12 credits)
  - Requirements: AMFG401 and 9 credits of electives (see Table 1)
- Minor (18 credits)
  - Requirements: AMFG401 and 15 credits of electives (see Table 1)

Table 1: Undergraduate elective courses, listed by specialty area (AMFG531, AMFG 511 and FEGN 526 require approval by appropriate program directors)

Additive Manufacturing of Structural Materials		
MEGN381	MANUFACTURING PROCESSES	3.0
MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
AMFG421	DESIGN FOR ADDITIVE MANUFACTURING	3.0
AMFG531	MATERIALS FOR ADDITIVE MANUFACTURING	3.0
AMFG498	SPECIAL TOPICS IN ADVANCED MANUFACTURING	1-6
AMFG511	DATA DRIVEN ADVANCED MANUFACTURING	3.0

FEGN525	ADVANCED FEA THEORY & PRACTICE	3.0
FEGN526	STATIC AND DYNAMIC APPLICATIONS IN FEA	3.0

Courses

AMFG401. ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
Additive Manufacturing (AM), also known as 3D Printing in the popular press, is an emerging manufacturing technology that will see widespread adoption across a wide range of industries during your career. Subtractive Manufacturing (SM) technologies (CNCs, drill presses, lathes, etc.) have been an industry mainstay for over 100 years. The transition from SM to AM technologies, the blending of SM and AM technologies, and other developments in the manufacturing world has direct impact on how we design and manufacture products. This course will prepare students for the new design and manufacturing environment that AM is unlocking. 3 hours lecture; 3 semester hours. Prerequisites: MEGN200 and MEGN201 or equivalent project classes.

AMFG421. DESIGN FOR ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
(II) Design for Additive Manufacturing (DAM) introduces common considerations that must be addressed to successfully design or re-design parts for additive manufacturing methods. Industry-leading hardware and FEA software will be used to explore all phases of the DAM workflow, including topology optimization, additive process simulation, distortion compensation, and in-service performance. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Execute a topology optimization, interpret results, and re-parameterize geometry to facilitate downstream shape/design refinement.
- 2. Explain the key factors driving support placement in an AM part.
- 3. Use software tools to plan the tool path for an AM process.
- 4. Set part orientation in an AM process to minimize surface area or volume of support material.
- 5. Simulate the thermal history of a part manufactured using an AM process.
- 6. Simulate post-production heat treatment for an AM process.
- 7. Optimize part orientation in a powder-bed AM process to minimize part distortion or maximize in-service fatigue life.
- 8. Clearly communicate in writing the findings of an AM design verification evaluation.

AMFG422. LEAN MANUFACTURING. 3.0 Semester Hrs.
Throughout the course, students will learn to apply skillsets to real world problems, focusing on lean and six-sigma principles and methodologies. The course is taught with a focus on the DMAIC structure of implementation (Define, Measure, Analyze, Improve and Control) for improving and implementing process efficiencies in industry. The course is split into three general subject areas; 1) Lean manufacturing principles, 2) six-sigma and statistical process control (SPC) methodologies and 3) Implementation techniques focusing on graphical and numerical representation of processes using R. Students will receive an in-depth overview of Lean manufacturing principles and will perform case studies at local industries to implement learned skill-sets. Next, students will step-through several hands-on activities using real products to investigate six-sigma and perform SPC analysis, identifying shifts in process data and learning how to shift processes into capable processes. Lastly, students will learn about various implementation techniques for industry and will perform an in-depth analysis of the course topics based on the industry tours performed. Prerequisite: MEGN381.

Course Learning Outcomes

- Critique real-time manufacturing processes with regards to information flow, product flow and process times.
- Identify value adding steps in manufacturing processes in order to better understand where waste lies
- Recognize real-time wastes in manufacturing processes and facilities and reorganize processes using efficiency models and learned skill-sets to reduce defects found throughout the process
- Implement lean and six-sigma methodologies to eliminate waste and decrease defects from observed and analyzed processes
- Utilize R and MiniTab software to create control charts
- Recognize when to use various applied statistical graphical and numerical representation to understand a process
- Create analytic reports discussing change implementation plans based on real-time data for upper level management to implement for process efficiency
- Apply learned skillsets to real-time manufacturing processes and facilities

AMFG423. DESIGN AND ANALYSIS OF EXPERIMENTS. 3.0 Semester Hrs.
This course introduces effective experimental design and analysis methodologies relevant to all engineering and scientific disciplines to maximize the information learned from every experiment (test case) while minimizing the total number of tests. We will be using state-of-art methods steeped in statistics to effectively set up your experiments, understand what the results are telling you, and clearly communicate the results to peers and leadership. We apply a disciplined systems engineering approach across the four major experimental phases: plan, design, execute, and analyze. This hands-on class will focus on understanding concepts and practical applications while relying less on the statistical theoretical development. Prerequisite: MATH 201 is recommended, not required.
Course Learning Outcomes

- At the completion of this course, students will: 1) Formulate an analytically defensible test strategy using foundational principles across the Plan-Design-Execute-Analyze phases of experimentation.
- 2) Apply statistically-based methods to understand results and quantify risk from single factor experiments.
- 3) Create and analyze full-factorial test designs with multiple input explanatory variables understanding the critical importance of interactions.
- 4) Construct appropriate test designs to screen many possible input factors to isolate those few variables that drive system behavior.
- 5) Construct response surface test designs that build on screening methods to characterize nonlinear behavior often seen in practical applications.
- 6) Compare alternative experimental designs with statistically-based performance metrics.
- 7) Assess advanced experimental designs that better fit the actual test environment rather than forcing the problem to conform into a common design.

AMFG498. SPECIAL TOPICS IN ADVANCED MANUFACTURING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only

once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

Biology Minor

Program Offered

- Minor in Biology

Program Description

The biology minor is designed for students outside of the Quantitative Biosciences and Engineering (QBE) major who would like to complement their degree specific learning with knowledge of fundamental biology concepts as well as modern technical applications of biological knowledge. Our understanding of biology is growing exponentially, allowing us to begin engineering biological systems to improve the environment and human health. This minor is open to students from any program outside of QBE and is specifically valuable to students interested in the interdisciplinary applications of their degree with biological systems to address issues impacting earth, energy, and the environment.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Minor in Biology

The minor requires 18 credits, which includes 8 credits of required courses and at least 10 credits of elective courses. At least 9 credits must not double count with the major, other than free electives.

Students pursuing the bachelor of science degree in quantitative biosciences and engineering (QBE) are not eligible to pursue the minor in biology as the course requirements and content do not significantly differ.

Special topics courses related to biology may be approved on a case-by-case basis. Additional classes with biological content may be approved by the minor director.

Required courses:

CBEN110	FUNDAMENTALS OF BIOLOGY I	4.0
CBEN120	FUNDAMENTALS OF BIOLOGY II	4.0
BIOL ELECT	Biology Elective Courses	10.0
Total Semester Hrs		**18.0**

ELECTIVE COURSES		
BIOL300	INTRODUCTION TO QUANTITATIVE BIOLOGY I	3.0
BIOL301	INTRODUCTION TO QUANTITATIVE BIOLOGY II	3.0
BIOL 499	RESEARCH PROJECT OR INTERNSHIP	3.0
CBEN304	ANATOMY AND PHYSIOLOGY	3.0
CBEN311	INTRODUCTION TO NEUROSCIENCE	3.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN321	INTRO TO GENETICS	4.0
CBEN322	BIOLOGICAL PSYCHOLOGY	3.0
CBEN324	INTRODUCTION TO BREWING SCIENCE	3.0
CBEN411	NEUROSCIENCE, MEMORY, AND LEARNING	3.0
CBEN412	INTRODUCTION TO PHARMACOLOGY	3.0
CBEN413	QUANTITATIVE HUMAN BIOLOGY	3.0
CBEN431	IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS	3.0
CEEN460	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
CEEN461	FUNDAMENTALS OF ECOLOGY	3.0
CHGN409	BIOLOGICAL INORGANIC CHEMISTRY	3.0
CHGN428	BIOCHEMISTRY	3.0
CHGN429	BIOCHEMISTRY II	3.0
CHGN441	THE CHEMISTRY AND BIOCHEMISTRY OF PHARMACEUTICALS	3.0
CHGN462	MICROBIOLOGY	3.0
CSCI303	INTRODUCTION TO DATA SCIENCE	3.0
MATH431	MATHEMATICAL BIOLOGY	3.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
MTGN472	BIOMATERIALS I	3.0

Energy

Programs Offered

- Minor in Energy
- Area of Special Interest in Energy

The discovery, production, and use of energy in modern societies have profound and far-reaching economic, political, and environmental effects. As energy is one of Mines core statutory missions, several Mines departments have come together to offer minor and Area of Special Interest (ASI) programs related to Energy. The 18-credit Energy minor adds value to any Mines undergraduate degree program by not only addressing the scientific and technical aspects of energy production and use but its broader social impacts as well. The Energy minor program is intended to provide engineering students with a deeper understanding of the complex role energy technology plays in modern societies by meeting the following learning objectives:

1. Students will gain a broad understanding of the scientific, engineering, environmental, economic, and social aspects of the production, delivery, and utilization of energy as it relates to the support of current and future civilization both regional and worldwide.
2. Students will develop depth or breadth in their scientific and engineering understanding of energy technology.
3. Students will be able to apply their knowledge of energy science and technology to societal problems requiring economic, scientific, technical analysis, and innovation while working in a multidisciplinary environment and be able to communicate effectively the outcomes of their analyses in written and oral form.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Program Requirements

Minor in Energy

Minimum 18 credits required:

Required Courses (6 credits)

ENGY200	INTRODUCTION TO ENERGY	3.0
EBGN330	ENERGY ECONOMICS	3.0

Policy Course: Select at least one of the following (minimum 3 credits)

HASS490	ENERGY AND SOCIETY	3.0
HASS491	ENERGY POLITICS	3.0

Select the remaining electives from the following:

Social Sciences and Law		
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
HASS419	ENVIRONMENTAL COMMUNICATION	3.0
HASS464	HISTORY OF ENERGY AND THE ENVIRONMENT	3.0
PEGN430	ENVIRONMENTAL LAW AND SUSTAINABILITY	3.0
All Energy Sources		
CBEN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
or MTGN469	FUEL CELL SCIENCE AND TECHNOLOGY	
or MEGN469	FUEL CELL SCIENCE AND TECHNOLOGY	
or MTGN469	FUEL CELL SCIENCE AND TECHNOLOGY	
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0
EENG481	ANALYSIS AND DESIGN OF ADVANCED ENERGY SYSTEMS	3.0
EENG489	COMPUTATIONAL METHODS IN ENERGY SYSTEMS AND POWER ELECTRONICS	3.0
ENGY497	SUMMER PROGRAMS	1-6
ENGY498	SPECIAL TOPICS	1-6
GEOL315	SEDIMENTOLOGY AND STRATIGRAPHY	3.0
Nuclear Energy		
ENGY340	NUCLEAR ENERGY	3.0
NUGN506	NUCLEAR FUEL CYCLE	3.0
NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
Sustainable Energy		
ENGY320	INTRO TO RENEWABLE ENERGY	3.0
ENGY350	GEOTHERMAL ENERGY	3.0
CEEN493	SUSTAINABLE ENGINEERING DESIGN	3.0
CHGN311	INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY	3.0
EENG390	ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID	3.0
EENG475	INTERCONNECTION OF RENEWABLE ENERGY, INTEGRATED POWER ELECTRONICS, POWER SYSTEMS, AND POWER QUALITY	3.0
EENG589	DESIGN AND CONTROL OF WIND ENERGY SYSTEMS	3.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0
Fossil Fuels		
PEGN201	PETROLEUM ENGINEERING FUNDAMENTALS	3.0
ENGY310	INTRO TO FOSSIL ENERGY	3.0
CBEN480	NATURAL GAS HYDRATES	3.0
MNGN438	GEOSTATISTICS	3.0
PEGN251	FLUID MECHANICS	3.0
PEGN305	COMPUTATIONAL METHODS IN PETROLEUM ENGINEERING	2.0
PEGN308	RESERVOIR ROCK PROPERTIES	3.0
PEGN450	ENERGY ENGINEERING	3.0
ENGY	Additional courses with energy content may be approved by the director or co-director of the energy minor.	

Area of Special Interest in Energy

Minimum of 12 credits of acceptable course work:

ENGY200	INTRODUCTION TO ENERGY	3.0
EBGN330	ENERGY ECONOMICS	3.0
Two additional energy-related courses		6.0
Total Semester Hrs		**12.0**

Courses

ENGY200. INTRODUCTION TO ENERGY. 3.0 Semester Hrs.
Introduction to Energy. Survey of human-produced energy technologies including steam, hydro, fossil (petroleum, coal, and unconventionals), geothermal, wind, solar, biofuels, nuclear, and fuel cells. Current and possible future energy transmission and efficiency. Evaluation of different energy sources in terms of a feasibility matrix of technical, economic, environmental, and political aspects. 3 hours lecture; 3 semester hours.

ENGY310. INTRO TO FOSSIL ENERGY. 3.0 Semester Hrs.
Students will learn about conventional coal, oil, and gas energy sources across the full course of exploitation, from their geologic origin, through discovery, extraction, processing, processing, marketing, and finally to their end-use in society. Students will be introduced to the key technical concepts of flow through rock, the geothermal temperature and pressure gradients, hydrostatics, and structural statics as needed to understand the key technical challenges of mining, drilling, and production. Students will then be introduced to unconventional (emerging) fossil-based resources, noting the key drivers and hurdles associated with their development. Students will learn to quantify the societal cost and benefits of each fossil resource across the full course of exploitation and in a final project will propose or evaluate a national or global fossil energy strategy, supporting their arguments with quantitative technical analysis. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- no change

ENGY320. INTRO TO RENEWABLE ENERGY. 3.0 Semester Hrs.
Survey of renewable sources of energy. The basic science behind renewable forms of energy production, technologies for renewable energy storage, distribution, and utilization, production of alternative fuels, intermittency, natural resource utilization, efficiency and cost analysis and environmental impact. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- no change

ENGY340. NUCLEAR ENERGY. 3.0 Semester Hrs.
Survey of nuclear energy and the nuclear fuel cycle including the basic principles of nuclear fission and an introduction to basic nuclear reactor design and operation. Nuclear fuel, uranium resources, distribution, and fuel fabrication, conversion and breeding. Nuclear safety, nuclear waste, nuclear weapons and proliferation as well economic, environmental and political impacts of nuclear energy. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- no change

ENGY350. GEOTHERMAL ENERGY. 3.0 Semester Hrs.
Geothermal energy resources and their utilization, based on geoscience and engineering perspectives. Geoscience topics include world wide occurrences of resources and their classification, heat and mass transfer, geothermal reservoirs, hydrothermal geochemistry, exploration methods, and resource assessment. Engineering topics include thermodynamics of water, power cycles, electricity generation, drilling and well measurements, reservoir-surface engineering, and direct utilization. Economic and environmental considerations and case studies are also presented. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- no change

ENGY399. INDEPENDENT STUDY. 0.5-6 Semester Hr.
Students can do individual research or special problem projects supervised by a faculty member. The student and instructor will agree on the subject matter, content, and credit hours.

ENGY499. INDEPENDENT STUDY. 0.5-6 Semester Hr.
Students can do individual research or special problem projects supervised by a faculty member. The student and instructor will agree on the subject matter, content, and credit hours.

Emeritus Professor

Ramona M. Graves, Petroleum Engineering

Professors

Roderick G. Eggert, Economics and Business

Linda Figueroa, Civil and Environmental Engineering

Andrew Herring, Chemical and Biological Engineering

Mark Jensen, Chemistry

Kathryn Johnson, Electrical Engineering

Jeffrey C. King, Metallurgical and Materials Engineering

Angus Rockett, Metallurgical and Materials Engineering

Roel Snieder, Geophysics

Associate Professors

Kathleen Hancock, Co-Director, Humanities, Arts, and Social Sciences

Masami Nakagawa, Mining Engineering

Timothy R. Ohno, Co-Director, Physics

Neal Sullivan, Mechanical Engineering

Teaching Professors

Linda Battalora, Petroleum Engineering

Joseph Horan, Humanities, Arts and Social Sciences

Teaching Associate Professor

John Persichetti, Engineering, Design and Society

Guy T. McBride, Jr. Honors Program in Public Affairs

Program Educational Objectives

The McBride Honors Program in Public Affairs offers an honors minor consisting of seminar courses with the primary goal of providing the opportunity to the students that apply and are selected for the program to cross the boundaries of their technical expertise into the ethical, cultural, socio-political, and environmental dimensions of human life. Students will develop their skills in communication, critical and creative thinking, and leadership through seminar-style classes that explore diverse aspects of the human experience. The seminars are designed to offer coherent perspectives across the curriculum, allowing for a maximum degree of discussion and debate on complex topics. Themes, approaches, and perspectives from the humanities and the social sciences are integrated with science and engineering perspectives to develop in students habits of thought necessary for a comprehensive understanding of societal and cultural issues that enhance critical thinking, creativity, social responsibility, and enlightened leadership.

Program Description

The McBride Honors Program minor is a 21-credit hour curriculum.

The program is delivered primarily in an interdisciplinary seminar format that maximizes discussion, debate, and innovative activities. Seminars are taught by dedicated faculty members from the humanities, social sciences, life sciences and physical sciences, and engineering. The curriculum of the McBride Honors Program includes the following features and educational experiences:

- Student-centered seminars guided by faculty collaborators from various disciplines.
- An interdisciplinary approach that integrates domestic and global perspectives into the curriculum.
- One-to-one long-lasting intellectual relationships and camaraderie among students and between faculty and students.
- The development and practice of oral/written communication, argumentation, and listening skills.
- The opportunity to develop an individualized learning experience which may involve study abroad, service learning, research, entrepreneurial projects, and/or professional internships.

An important experience in the program is engaging in a practicum (e.g., an internship, overseas study, public service, or undergraduate research experience). Because engineers and scientists will continue to assume significant responsibilities as leaders in public and private sectors, it is essential that CSM students be prepared for more than their traditional "first jobs". Leadership and management demand an understanding of the accelerating pace of change that marks the social, political, economic, and environmental currents of society and a commitment to social and environmental responsibility. Regardless of their career goals, however, this same understanding is demanded of an educated person in the contemporary world. While the seminars in the program are designed to nourish such an understanding, these practicum experiences allow students to see firsthand the kinds of challenges that they will face in their professional and personal lives and to engage with the world as their classroom.

Foreign study is also possible either through CSM-sponsored trips or through individual plans arranged in consultation with the director and the Office of International Programs. The program offers some competitive funding opportunities to selected students to facilitate study abroad or other exceptional educational experiences. Please contact the director or see the program webpage for more information.

Student Profile

The McBride Honors Program in Public Affairs seeks to enroll students who can benefit most from the learning experiences upon which the program is based while significantly contributing to the broader learning objectives of the McBride community. Most honors programs admit students exclusively on the basis of academic record. Although the McBride Honors Program uses SAT and ACT test scores and grade-point average as important indicators of success in the McBride Program, they form only part of the criteria used in the admission process. The McBride Program also examines extracurricular activities, interest in human affairs, evidence of a mindset of curiosity and exploration, and the willingness to engage actively in discussion and debate. Applicants must demonstrate their commitment to public service, their leadership potential, their intrinsic motivation to learn, willingness to understand and respect perspectives other than their own, and writing, listening, and speaking abilities.

Once admitted into the program, a McBride student commits to:

- completing the McBride curriculum as stated in the catalog.
- participating in the McBride seminars as an active and responsible member of the learning community, always completing reading and writing assignments on time in order to be ready to learn.
- engaging in the highest level of intellectual discourse in a civil and respectful manner with all members of the CSM community, particularly with those who hold different beliefs, values, and views.
- understanding that the McBride faculty are committed to provide the best education to help students become thoughtful and responsible persons, citizens, and professionals.
- upholding the highest standards of ethical conduct and the CSM Honor Code, particularly those related to academic honesty and respect for peers, instructors, and Program administrators.

Although the educational experiences in the McBride Honors Program are rigorous and demand a high degree of dedication from the students, McBride graduates have gained positions of their choice in industry, business, government, and within non-governmental organizations, or in other professions more easily than others, and have been successful in winning admission to high-quality graduate, law, medicine, and other professional schools.

Admission

Students typically begin the program in the fall of their sophomore year, although in some cases transfer students and juniors may join the program. Students should apply to the McBride Program by the deadline set by the program by filling out an application, submitting the required materials, and securing a letter of recommendation (see webpage for details at https://mcbride.mines.edu/), and participating in an interview.

Note: Students must complete HASS100 Nature and Human Values or HNRS105 & HNRS115, Innovation and Discovery in Engineering, Arts and Sciences, prior to, or concurrently with, enrolling in the first course, HNRS305 Explorations in Modern America or HNRS315 Explorations in the Modern World.

Culture and Society (CAS) Core Curriculum Requirements

Students completing the McBride Honors Program are required to complete HASS100"Nature and Human Values," or HNRS105 & HNRS115, "Innovation and Discovery in Engineering, Arts and Sciences " and EBGN201, "Principles of Economics." McBride students who have completed HRNS315 are exempt from completing HASS200, "Human Systems."

Transfer and Graduation Policies

The McBride Program accepts applications from transfer students as follows:

Transfer students must complete and submit an application and participate in the interview process like other applicants under the time frame set by the program. Transfer students should expect to complete the entire McBride curriculum, but under some circumstances, transfer students may petition the director for course substitutions.

Academic Standards

Students must perform to the highest levels of writing, reading, and discussion in preparation for and during McBride seminars. Participation in class projects and discussions is essential. Students who do not maintain an appropriate level of participation and engagement may be asked to leave the Program.

Academic integrity and honesty are expected of all Mines students. Any infractions in these areas will be handled under the rules of CSM and the McBride Program and may result in dismissal from the program. The program demands a high level of achievement not only in Honors courses, but in all academic work attempted at CSM. To that end, a student must meet the following minimum requirements:

- A minimum cumulative GPA 2.9 is required for admission. Failure to meet the GPA requirement will result in voiding the invitation to join the McBride Program or being placed on probation for one semester. If the required minimum GPA has not been met at the end of the probationary semester the student will be withdrawn from the program.
- A minimum cumulative GPA of 3.0 in Honors coursework is required to remain in good academic standing in the program. Students who drop below the minimum in their McBride coursework will be placed on probation for one semester. If the required minimum GPA has not been met at the end of the probationary semester, or in any subsequent semester, the student may be withdrawn from the program.
- A minimum *cumulative* GPA of 2.9 is required in all coursework at CSM. Students who drop below a cumulative GPA of 2.9 will be placed on probation for one semester. If the required minimum GPA has not been met at the end of the probationary semester, or in any subsequent semester, the student will be withdrawn from the program.

- The minimum *cumulative GPA* and the minimum *Honors GPA* at the time of graduation are required in order to receive the Minor in the McBride Honors Program in Public Affairs. Graduating seniors who fall below these minima will receive a Minor in Public Affairs without the Honors designation if they choose to complete the Public Affairs minor instead of transferring their credits to the department of Humanities, Arts, and Social Sciences. Exemptions may be granted at the discretion of the program director.
- If students wish to appeal their withdrawal from the McBride Honors Program, they must write a letter of appeal to the director, who will review the student's case in consultation with McBride faculty.

Curriculum

The Curriculum Effective for Students Beginning Fall 2013

Each elective will follow a specific theme that provides an in-depth look at a particular problem or case study relating to the overarching topic of the course. These specific themes will change frequently. Prior to registration each semester, the course theme and description will be announced to all McBride students via email and posted on the McBride webpage. Students may take a given course twice if and only if the course theme is different.

Honors Core Courses (6 credits):		
HNRS305	EXPLORATIONS IN MODERN AMERICA	3.0
HNRS315	EXPLORATIONS IN THE MODERN WORLD	3.0
Honors Practicum Requirement (3 credits):		
HNRS405	MCBRIDE PRACTICUM	1-3
Honors Electives (12 credits):		
HNRS425	EXPLORATIONS IN POLITICS, POLICY, AND LEADERSHIP	3.0
HNRS430	EXPLORATIONS IN IDEAS, ETHICS, AND RELIGION	3.0
HNRS435	EXPLORATIONS IN CULTURE, SOCIETY, AND CREATIVE ARTS	3.0
HNRS440	EXPLORATIONS IN INTERNATIONAL STUDIES & GLOBAL AFFAIRS	3.0
HNRS445	EXPLORATIONS IN SCIENCE, TECHNOLOGY, AND SOCIETY	3.0
HNRS450	EXPLORATIONS IN EARTH, ENERGY, AND ENVIRONMENT	3.0
Special Topics		
HNRS398	SPECIAL TOPICS IN THE UNIVERSITY HONORS AND SCHOLARS PROGRAM	1-6
HNRS498	SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS	1-6
HNRS499	INDEPENDENT STUDY	1-6

HNRS305. EXPLORATIONS IN MODERN AMERICA. 3.0 Semester Hrs.
(WI) Honors core course that develops student skills in reading, writing, critical thinking, and oral communication. skills through the exploration of selected topics related to the social, cultural, and political ideas and events that have shaped the development of the modern United States and its role in the world. 3 lecture hours, 3 credit hours. Prerequisite: HASS100 or HNRS105, HNRS115 or HNRS110, HNRS120 or HNRS198A.

HNRS315. EXPLORATIONS IN THE MODERN WORLD. 3.0 Semester Hrs.
(WI) Honors core course that develops student writing skills and critical thinking abilities through the exploration of selected topics related to the social, cultural, and political ideas and developments that have shaped the modern world. 3 lecture hours, 3 credit hours. Prerequisite: HASS100 or HNRS105, HNRS115 or HNRS110, HNRS120 or HNRS198A.

HNRS405. MCBRIDE PRACTICUM. 1-3 Semester Hr.
(I, II) (WI) With approval of the Program, a McBride student may enroll in an individualized study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. This option may be used to pursue an approved foreign study program, service learning program, international internship, undergraduate research project, or other authorized experiential learning program of study. Students must also prepare a faculty-guided major research paper that integrates the experience with the goals, objectives, and focus of the Honors Program in Public Affairs. 1-3 semester hours. Repeatable up to 6 hours.

HNRS425. EXPLORATIONS IN POLITICS, POLICY, AND LEADERSHIP. 3.0 Semester Hrs.
(WI) Study of selected topics related to policy, politics, and/or leadership through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in The Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS430. EXPLORATIONS IN IDEAS, ETHICS, AND RELIGION. 3.0 Semester Hrs.
(WI) Study of selected topics related to ideas, ethics, and/or religion through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS435. EXPLORATIONS IN CULTURE, SOCIETY, AND CREATIVE ARTS. 3.0 Semester Hrs.
(WI) Study of selected topics related to culture, society, and/or the creative arts through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS440. EXPLORATIONS IN INTERNATIONAL STUDIES & GLOBAL AFFAIRS. 3.0 Semester Hrs.
(WI) Study of selected topics related to international studies and/or global affairs through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS445. EXPLORATIONS IN SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.
(WI) Study of selected topics related to the relationships between science, technology, and society through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS450. EXPLORATIONS IN EARTH, ENERGY, AND ENVIRONMENT. 3.0 Semester Hrs.
(WI) Study of selected topics related to earth, energy, and/or the environment through case studies, readings, research, and writing. This course may focus on the human dimensions or broader impacts of science, technology, engineering, or mathematics. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations

in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS476. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.

(II) Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student?s learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. Prerequisites: none. 2 hours lecture; 3-4 hours lab; 3.0 semester hours.

HNRS498. SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS. 1-6 Semester Hr.

A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS499. INDEPENDENT STUDY. 1-6 Semester Hr.

Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

Teaching Professor

Professor Toni Lefton, Executive Director, University Honors & Scholars Programs

Teaching Associate Professors

Professor Melanie Brandt, McBride Honors Program Director

Professor Justin Latici, McBride Practicum Advisor

Operations Research

Minor Program in Operations Research (OR)

The Operations Research minor consists of a minimum of 18 credit hours of a logical sequence of courses. Only three of these hours may be taken in the student's degree-granting department. Three of these hours must consist of a deterministic modeling course, three must consist of a stochastic modeling course, and no more than three must draw from a survey course (combining both stochastic and deterministic modeling).

The objectives of the minor are to supplement an engineering or applied science background with a formal approach to mathematical modeling that includes assessing and/or improving the performance of a system. Such a system could be naturally occurring or manmade. Examples of such systems are manufacturing lines, mines, wind farms, mechanical systems, such as turbines and generators (or a collection of such objects), waste water treatment facilities, and chemical processes. The formal approach includes optimization, (e.g., linear programming, nonlinear programming, integer programming), decision analysis, stochastic modeling, and simulation.

Deterministic Modeling (minimum of one)

CSCI262	DATA STRUCTURES	3.0
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI406	ALGORITHMS	3.0
MATH332	LINEAR ALGEBRA	3.0
EBGN455	LINEAR PROGRAMMING	3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG417	MODERN CONTROL DESIGN	3.0
MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
MEGN588	INTEGER OPTIMIZATION	3.0

Stochastic Modeling (minimum of one)

MTGN350	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS	3.0
EBGN459	SUPPLY CHAIN MANAGEMENT	3.0
EBGN461	STOCHASTIC MODELS IN MANAGEMENT SCIENCE	3.0
EBGN528	INDUSTRIAL SYSTEMS SIMULATION	3.0
EBGN560	DECISION ANALYTICS	3.0
MATH324	STATISTICAL MODELING	3.0
MATH438	STOCHASTIC MODELS	3.0
MNGN438	GEOSTATISTICS	3.0
PEGN438	PETROLEUM DATA ANALYTICS	3.0

Survey Course (Maximum of one)

MNGN433	MINE SYSTEMS ANALYSIS I	3.0

Quantum Engineering

Minor Program in Quantum Engineering

Quantum Engineering is an interdisciplinary program that seeks to equip students for careers in emerging technologies in quantum information sciences. It encompasses a wide range of disciplines that include chemistry, computer science, electrical engineering, mathematics, materials science, and physics and is necessarily a collaborative effort among many Mines departments.

Quantum Engineering Minor

Quantum Engineering is an interdisciplinary program that seeks to equip students for careers in emerging technologies in quantum information sciences. It encompasses a wide range of disciplines that include chemistry, computer science, electrical engineering, mathematics, materials science, and physics and is necessarily a collaborative effort among many Mines departments.

The interdisciplinary minor in Quantum Engineering requires 18 credits.

QE minor students will be required to take Honors Linear Algebra (MATH342) or Linear Algebra (MATH332) and three of the following courses: Quantum Programming (CSCI481/CSCI581), Low Temperature Microwave Measurement (EENG432/EENG532), Solid State Physics

Applications and Phenomena (PHGN441), Microelectronics Processing (PHGN435), and Fundamentals of Quantum Information (PHYS519).

Students may select an additional 2 courses from the list above or the following list to further increase specialization:		
PHGN440	SOLID STATE PHYSICS	3.0
PHGN466	MODERN OPTICAL ENGINEERING	3.0
PHGN480	LASER PHYSICS	3.0
CSCI423	COMPUTER SIMULATION	3.0
CSCI440	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING	3.0
CSCI474	INTRODUCTION TO CRYPTOGRAPHY	3.0
MTGN211	STRUCTURE OF MATERIALS	3.0
MTGN315	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS	3.0
MTGN350	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS	3.0
MTGN352	METALLURGICAL AND MATERIALS KINETICS	3.0
MTGN456	ELECTRON MICROSCOPY	2.0
MTGN473	COMPUTATIONAL MATERIALS	3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG383	EMBEDDED SYSTEMS	4.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0
EENG411	DIGITAL SIGNAL PROCESSING	3.0
EENG421	SEMICONDUCTOR DEVICE PHYSICS AND DESIGN	3.0
EENG428/430	COMPUTATIONAL ELECTROMAGNETICS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MATH438	STOCHASTIC MODELS	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH458	ABSTRACT ALGEBRA	3.0

Space and Planetary Science and Engineering

Program Offered

Area of Special Interest in Space and Planetary Science and Engineering

Program Description

The Space and Planetary Science and Engineering Program offers an Area of Special Interest for students interested in the science, engineering, and exploration of space. This program brings together courses from several Mines departments and programs covering a diverse array of topics, including planetary science, astronomy, space physics, and the design of engineering systems for space exploration. The curriculum can be chosen from a list of approved courses, in consultation with an SPSE program advisor. Interested students should contact SPSE Program Director Dr. Angel Abbud-Madrid at **aabbudma@mines.edu. (aabbudma@mines.edu)**

Since the advent of the space age in the middle of the last century, the pace of human and robotic exploration of space has been ever increasing. This exploration is made possible by feats of engineering to allow long-term operation of robotic systems and human explorers in the harsh environment of space. The product of this exploration is a large and growing body of knowledge about our neighbors in the solar system and our place in the universe. The mission of the Space and Planetary Science and Engineering (SPSE) program is to provide students with a pathway for studying extraterrestrial applications of science, engineering, and resource utilization through an Area of Special Interest.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Program Requirements

Area of Special Interest in Space and Planetary Science and Engineering:

Enrollment in the Area of Special Interest is approved by the director. Students will then be assigned to an SPSE ASI advisor from among the affiliated faculty, who will monitor and advise their progress. The Area of Special Interest requires a total of 12 credits, up to 3 of which may be at the 200-level or below and up to 3 of which may overlap with the requirements of the degree-granting program. Students may choose their ASI courses from the list of approved courses below or from any additional courses approved by the student's ASI advisor. Application of EDNS Cornerstone or Capstone project credits towards the ASI requires choice of a space or planetary related project and approval by the student's SPSE ASI advisor.

SPSE-approved Courses		
EDNS251	CORNERSTONE DESIGN II	3.0
EDNS491	CAPSTONE DESIGN I	3.0
EDNS492	CAPSTONE DESIGN II	3.0
GEGN469	ENGINEERING GEOLOGY DESIGN	3.0
GEOL410	PLANETARY GEOLOGY	3.0
GPGN438	GEOPHYSICS PROJECT DESIGN	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
PHGN418	GENERAL RELATIVITY	3.0
PHGN324	INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS	3.0
PHGN423	PARTICLE PHYSICS	3.0
PHGN471 & PHGN481	SENIOR DESIGN PRINCIPLES I and SENIOR DESIGN PRACTICE	3.0
PHGN472 & PHGN482	SENIOR DESIGN PRINCIPLES II and SENIOR DESIGN PRACTICE	3.0
MEGN451	AERODYNAMICS	3.0
MEGN453	AEROSPACE STRUCTURES	3.0

Director, SPSE Area of Special Interest

Angel Abbud-Madrid, Mechanical Engineering & Space Resources

Affiliated Faculty

Christopher Dreyer, Mechanical Engineering & Space Resources

Alex Flournoy, Physics

Leslie Lamberson, Mechanical Engineering

Derrick Rodriguez, Mechanical Engineering

Frederic Sarazin, Physics

Paul Sava, Geophysics

Matthew Siegfried, Geophysics

George Sowers, Mechanical Engineering & Space Resources Program

John Spear, Civil and Environmental Engineering

Neal Sullivan, Mechanical Engineering

Lesli Wood, Geology and Geological Engineering

Teaching

Programs Offered

- Minor in Teaching
- Minor in Teaching with Licensure
- Bachelor of Science in Design Engineering with a STEM Teaching Focus Area (see Engineering, Design, and Society)

Teach@Mines is an interdisciplinary program designed to prepare undergraduate and graduate students as well as Mines alumni or career changers to teach at any level from elementary to university level instruction. A variety of pathways have been created to support students at any point in their academic journey. The coursework prepares students to teach using best-practices from mathematics, science, engineering, and computer science education research.

Colorado Teacher Licensure

- Secondary Science (Grades 7-12)
- Secondary Mathematics (Grades 7-12)
- Middle School Mathematics (Grades 6-8)
- Computer Science (Grades K-12)

For those interested in other subject areas, Teach@Mines can help with advising and preliminary coursework.

Any student at Mines can add Colorado teacher licensure to their degree. The state requires 24 credits of coursework that includes 800 hours of K-12 field experience. This coursework can be completed simply for the purpose of earning licensure or as part of a minor, major, or Master's degree. The full 24 credits of required coursework is built into the Teaching Minor with Licensure, the Bachelor's degree in Design Engineering with a STEM Teaching Focus Area and the Masters in STEM Education.

LICENSURE COURSEWORK :

To earn licensure in the State of Colorado students must complete 24 credits of coursework along with 800 hours of K-12 field experience. The courses below provide the opportunities to complete the full 800 hours.

Core courses (9 credits)

- SCED262 – K-12 Field Experience & Building Student Relationships (3 credits)
- SCED333 – Educational Psychology & Assessment (3 credits) *****
- SCED363 – Dynamic Teaching: Motivation, Classroom Management, and Differentiation of Instruction (3 credits) *****

Teaching techniques (3 credits - Choose One)

- CSED435 – Computer Science Teaching Techniques (3 credits)
- MAED425 Pre-Algebra and Algebra Teaching Techniques (3 credits)
- SCED445 Physics and Chemistry Teaching Techniques (3 credits)\

Practices in the field (3 credits - Choose One)

- SCED415 – Scientific Practices vs. Engineering Design & the Nature of Science (3 credits)
- CSED430 – Computer Science Practices and Technological Impacts on Society (3 credits)
- MAED405 – Mathematical Practices & the Social Context of Math (3 Credits)

Practicum and Student Teaching (9 credits)

- SCED/MAED/CSED 464 Capstone Curriculum Design I – Practicum (3 credits)
- SCED/MAED/CSED565 – Capstone Curriculum Design II – Student Teaching (6-12 credits)

PRIMARY CONTACT:

Wendy Adams, Director
303-273-3068
wkadams@mines.edu

Teaching Minor

To obtain a Teaching Minor, students must take at least 18 credits related to teacher education. Four specific courses are required: 3 credits of Field Experience (SCED262), Educational Psychology (SCED333), Dynamic Teaching (SCED363) and Capstone Curriculum Design (SCED464 or MAED464 or CSED464). Additionally, students will choose two additional courses, one from each category listed below.

Required Courses:		**9.0**
SCED262	K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS	
SCED333	EDUCATIONAL PSYCHOLOGY AND ASSESSMENT	
SCED363	DYNAMIC TEACHING: MOTIVATION, CLASSROOM MANAGEMENT, AND DIFFERENTIATION OF INSTRUCTION	
One of the following Required Courses:		**3.0**
SCED464	CAPSTONE CURRICULUM DESIGN I	
MAED464	CAPSTONE CURRICULUM DESIGN I	
CSED464	CAPSTONE CURRICULUM DESIGN I - PRACTICUM	
One of the following Practices Courses:		**3.0**
MAED405	MATHEMATICAL PRACTICES AND THE SOCIAL CONTEXT OF MATHEMATICS	
SCED415	SCIENTIFIC PRACTICES VS ENGINEERING DESIGN AND THE NATURE OF SCIENCE	
CSED430	COMPUTER SCIENCE PRACTICES AND TECHNOLOGICAL IMPACTS ON SOCIETY	
One of the following Teaching Techniques Courses:		**3.0**
SCED445	PHYSICS AND CHEMISTRY TEACHING TECHNIQUES	
MAED425	PRE-ALGEBRA AND ALGEBRA TEACHING TECHNIQUES	

CSED435	COMPUTER SCIENCE TEACHING TECHNIQUES	
Total Semester Hrs		**18.0**

Teaching Minor with Licensure

To obtain a Teaching Minor with Licensure, students must take at least 24.0 credits related to teacher education. Five specific courses are required: 3 credits of Field Experience (SCED262), Educational Psychology (SCED333), Dynamic Teaching (SCED363) and Capstone Curriculum Design I (SCED464 or MAED464 or CSED464); 6 credits of Capstone Curriculum Design II (SCED465 or MAED465 or CSED465). Additionally, students will choose two additional courses, one from each category listed below.

Required Courses:		**9.0**
SCED262	K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS	
SCED333	EDUCATIONAL PSYCHOLOGY AND ASSESSMENT	
SCED363	DYNAMIC TEACHING: MOTIVATION, CLASSROOM MANAGEMENT, AND DIFFERENTIATION OF INSTRUCTION	
One of the following Required Courses:		**3.0**
SCED464	CAPSTONE CURRICULUM DESIGN I	
MAED464	CAPSTONE CURRICULUM DESIGN I	
CSED464	CAPSTONE CURRICULUM DESIGN I - PRACTICUM	
One of the following Required Courses:		**6.0**
SCED465	CAPSTONE CURRICULUM DESIGN II	
MAED465	CAPSTONE CURRICULUM DESIGN II	
CSED465	CAPSTONE CURRICULUM DESIGN II - STUDENT TEACHING	
One of the following Practices Courses:		**3.0**
MAED405	MATHEMATICAL PRACTICES AND THE SOCIAL CONTEXT OF MATHEMATICS	
SCED415	SCIENTIFIC PRACTICES VS ENGINEERING DESIGN AND THE NATURE OF SCIENCE	
CSED430	COMPUTER SCIENCE PRACTICES AND TECHNOLOGICAL IMPACTS ON SOCIETY	
One of the following Teaching Techniques Courses:		**3.0**
SCED445	PHYSICS AND CHEMISTRY TEACHING TECHNIQUES	
MAED425	PRE-ALGEBRA AND ALGEBRA TEACHING TECHNIQUES	
CSED435	COMPUTER SCIENCE TEACHING TECHNIQUES	

Courses

CSED430. COMPUTER SCIENCE PRACTICES AND TECHNOLOGICAL IMPACTS ON SOCIETY. 3.0 Semester Hrs.
Students will explore current industry practices in computer science, the impacts major technological changes have had on society, and importantly, how to explicitly incorporate these topics into your teaching alongside computer science content. You will interact with these topics in the context of software engineering practices and examples and also zooming out to reflect on the future of computer science at a `meta? level. Students will explore research-based instruction of CS practices and ethics in K-12 through curriculum design and microteaching. Prerequisite: CSCI 128 or CSCI 101/102 or CSCI 200 or CSCI 220. Co-requisite: None.
Course Learning Outcomes

- A. Evaluate the impacts major technological changes have had on society (e.g., internet, mobile phones, AR/VR, AI).
- B. Analyze current effective computer science industry practices.
- C. Students will be able to engage in appropriate computer science practices and, as teachers, support their own students in doing the same.
- D. Students will be able to identify, adapt, and/or develop K-12 lessons to effectively develop students' understanding of computer science practices.
- E. Students will be able to integrate current issues and events related to computer science, and age-/grade-appropriate controversial topics presented from multiple perspectives into lessons using an analytical approach without bias.
- F. Students will be able to select, adapt, and/or develop lessons that explicitly engage students in directly learning about innovative computer science practices aligned with the Colorado Academic Standards.
- G. Students will be able to identify, adapt, and/or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations.
- H. Students will be able to clearly articulate their ideas in writing. This involves a. composing short synthesis opinion papers and longer research papers with an awareness about introductions, conclusions and topic sentences; b. incorporating and cite correctly all evidence used to support a text's claim/s.
- I. Students will be able to clearly articulate their ideas verbally. This involves a. delineating effective characteristics of multi-media presentations; b. articulating computer science practices in a way that K-12 students can understand and be motivated to explore these practices; and c. collaborating with others toward giving and receiving feedback on both oral and written work about teaching computer science practices.

CSED435. COMPUTER SCIENCE TEACHING TECHNIQUES. 3.0 Semester Hrs.
Students will investigate, practice teaching, deconstruct and design K-12 CS curriculum, instruction, and assessment by practicing curriculum design and teaching from elementary, middle school, and high school lesson plans. Interactive course activities include K-12 classroom observations and teacher guest speakers. Prerequisite: None. Co-requisite: None.
Course Learning Outcomes

- A. Students will apply knowledge of computational thinking and programming concepts to the creation of curriculum, appropriate instructional strategies, and related formative and summative assessments. 1. Students will demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations knowledge of: a. Computational thinking and programming concepts, namely: i. problem-solving skills, variables and control structures, abstraction and algorithms, including: 1. code comments, pseudocode, flowcharts and other documentation. 2. testing and debugging; ii. hardware and software systems, including: 1. inputs and outputs; 2. storage and the process of the transformation of data; 3. specific functions and use of hardware; 4. troubleshooting problems; iii. internet and network systems, including: 1. the internet's role as facilitator of the transfer of information; 2. a network as a series of interconnected devices and the internet as a series of interconnected networks; and 3. basic internet safety; iv. how to collect, store, transform, analyze, evaluate and secure data; and v. the impacts of computing, including: 1. the interaction between human and computing systems; 2. the history of computer science; 3. equity and access considerations; 4. laws and ethics associated with the field of computer science and the ramifications of the misuse of technology; and 5. tradeoffs between usability and security in hardware, networks, and the internet.

- B. Students will apply knowledge of computer science (CS) pedagogical theory and research-based instructional strategies incorporating age-appropriate and cultural and linguistically responsive curriculum and instruction based on national and state CS standards. 2. Students will demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations knowledge of and/or the ability to: a. create and foster an engaging environment in which all students develop the requisite computer science skills to participate more fully in a technologically based collaborative society; b. analyze and evaluate computer science curricula to ensure age- and grade-appropriate content; c. effectively integrate technology into instructional and assessment strategies, as appropriate to computer science education and the learner; d. perform laboratory-based, hands-on activities, including unplugged activities, block-based programming and third-generation programming language, that demonstrate grade-appropriate programming concepts and proficiency; and e. implement instructional practices and grade-appropriate applications on the interrelationships between the field of computer science and disparate content areas to: i. make concrete and abstract representations; and ii. connect computer science with real-world situations.
- C. Students will apply content knowledge of CS on a variety of subdisciplines, programming concepts, and interdisciplinary approaches to enact engaging and motivating learning. 3. Students will demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations knowledge of and/or the ability to effectively instruct: a. artificial intelligence; b. computational sciences; c. computer programming; d. cybersecurity; e. data science; f. hardware and network systems; g. machine learning; and h. robotics.
- D. Students will cultivate K-12 students’ CS identities by helping them realize the usefulness of CS by providing connections to students’ everyday lives. Build CS self-efficacy by encouraging persistence and demonstrating the belief that every student is capable of learning and expressing their creativity and intelligence with CS.4. Students will demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations knowledge of specific shifts in general instruction practices required for computer science education and the ability to assist K-12 students: a. develop resilience and perseverance with regard to computer science and computational learning experiences; b. attain a level of comfort with ambiguity and open-ended problems; c. see failure as an opportunity to learn and innovate; d. understand that computational thinking is a fundamental human ability and does not require a computer, and how that understanding can leverage the power of computers to solve a problem; e. recognize that not all problems can be solved computationally; and f. understand the role and importance of cybersecurity.
- E. Students will collaborate with others towards giving and receiving feedback on both oral and written work about teaching CS as a community of inquiry. 5. Students shall demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations the ability to self-assess and act upon feedback regarding the effectiveness of instruction based on the achievement of students.
- F. Students will develop an appreciation for teaching as a practice which requires ongoing study. 6. Students will demonstrate knowledge about pursuing continuous professional development through appropriate activities, coursework and participation in relevant professional organizations to keep abreast of the ever-changing developments in technology.

CSED464. CAPSTONE CURRICULUM DESIGN I - PRACTICUM. 3.0 Semester Hrs.

This course provides Mines students an intensive teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 100-hours field experience requirement in the student?s assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed/concurrent 3 credits of SCED 262; complete/concurrent with CSED 430 or CSED 435. Co-requisite: Completed/concurrent 3 credits of SCED 262; complete/concurrent with CSED 430 or CSED 435.

Course Learning Outcomes

- reflect on their practice and use this reflection to set goals for further growth.
- write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E’s (engage, explore, explain, elaborate and evaluate) or other learning cycle model, accommodations, formative assessment and subject integration.
- utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science, engineering or STEM, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- use formative-assessment techniques (10 or more) to evaluate students’ thinking during classroom activities and assess students’ progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.

- apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- engage in professional behavior expected of new teachers including a. appropriate dress, b. attendance and professional commitments, c. teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), d. respectful collaboration (even if do not agree), e. professional initiative, and f. student confidentiality related to both academic performance and personal lives.
- learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

CSED465. CAPSTONE CURRICULUM DESIGN II - STUDENT TEACHING. 6-12 Semester Hr.

This course provides Mines students an immersive student teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 32-hour per credit hour enrolled field experience requirement in the students assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a work sample (unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed CSED 464; completed/concurrent with SCED 333, SCED 363, CSED 430, and CSED 435. Co-requisite: Completed/concurrent with SCED 333, SCED 363, CSED 430, and CSED 435.

Course Learning Outcomes

- utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science, engineering or STEM, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- engage in professional behavior expected of new teachers including a. appropriate dress, b. attendance and professional commitments, c. teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), d. respectful collaboration (even if do not agree), e. professional initiative, and f. student confidentiality related to both academic performance and personal lives.
- learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

CSED498. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Repeatable for credit under different titles.

CSED530. COMPUTER SCIENCE PRACTICES AND TECHNOLOGICAL IMPACTS ON SOCIETY. 3.0 Semester Hrs.

Students will explore current industry practices in computer science, the impacts major technological changes have had on society, and importantly, how to explicitly incorporate these topics into your teaching alongside computer science content. They will interact with these topics in the context of software engineering practices and examples and also zooming out to reflect on the future of computer science at a `meta? level. Students will explore research-based instruction of CS practices and ethics in K-12 through curriculum design and microteaching. Prerequisite: CSCI 128 or CSCI 101/102 or CSCI 200 or CSCI 220. Co-requisite: None.

Course Learning Outcomes

- A. Evaluate the impacts major technological changes have had on society (e.g., internet, mobile phones, AR/VR, AI).
- B. Analyze current effective computer science industry practices.

- C. Students will be able to engage in appropriate computer science practices and, as teachers, support their own students in doing the same.
- D. Students will be able to identify, adapt, and/or develop K-12 lessons to effectively develop students' understanding of computer science practices.
- E. Students will be able to integrate current issues and events related to computer science, and age-/grade-appropriate controversial topics presented from multiple perspectives into lessons using an analytical approach without bias.
- F. Students will be able to select, adapt, and/or develop lessons that explicitly engage students in directly learning about innovative computer science practices aligned with the Colorado Academic Standards.
- G. Students will be able to identify, adapt, and/or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations.
- H. Students will be able to clearly articulate their ideas in writing. This involves a. composing short synthesis opinion papers and longer research papers with an awareness about introductions, conclusions and topic sentences; b. incorporating and cite correctly all evidence used to support a text's claim/s.
- I. Students will be able to clearly articulate their ideas verbally. This involves a. delineating effective characteristics of multi-media presentations; b. articulating computer science practices in a way that K-12 students can understand and be motivated to explore these practices; and c. collaborating with others toward giving and receiving feedback on both oral and written work about teaching computer science practices.

CSED535. COMPUTER SCIENCE TEACHING TECHNIQUES. 3.0 Semester Hrs.

Students will investigate, practice teaching, deconstruct and design K-12 CS curriculum, instruction, and assessment by practicing curriculum design and teaching from elementary, middle school, and high school lesson plans. Interactive course activities include K-12 classroom observations and teacher guest speakers. Prerequisite: None. Co-requisite: None.

Course Learning Outcomes

- A. Objective: Students will apply knowledge of computational thinking and programming concepts to the creation of curriculum, appropriate instructional strategies, and related formative and summative assessments. 1. Outcome: Students will demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations knowledge of: a. Computational thinking and programming concepts, namely: i. problem-solving skills, variables and control structures, abstraction and algorithms, including: 1. code comments, pseudocode, flowcharts and other documentation. 2. testing and debugging; ii. hardware and software systems, including: 1. inputs and outputs; 2. storage and the process of the transformation of data; 3. specific functions and use of hardware; 4. troubleshooting problems; iii. internet and network systems, including: 1. the internet's role as facilitator of the transfer of information; 2. a network as a series of interconnected devices and the internet as a series of interconnected networks; and 3. basic internet safety; iv. how to collect, store, transform, analyze, evaluate and secure data; and v. the impacts of computing, including: 1. the interaction between human and computing systems; 2. the history of computer science; 3. equity and access considerations; 4. laws and ethics associated with the field of computer science and the ramifications of the misuse of technology; and 5. tradeoffs between usability and security in hardware, networks, and the internet.
- B. Objective: Students will apply knowledge of computer science (CS) pedagogical theory and research-based instructional strategies incorporating age-appropriate and cultural and linguistically responsive curriculum and instruction based on national and state CS standards. 2. Outcome: Students will demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations knowledge of and/or the ability to: a. create and foster an engaging environment in which all students develop the requisite computer science skills to participate more fully in a technologically based collaborative society; b. analyze and evaluate computer science curricula to ensure age- and grade-appropriate content; c. effectively integrate technology into instructional and assessment strategies, as appropriate to computer science education and the learner; d. perform laboratory-based, hands-on activities, including unplugged activities, block-based programming and third-generation programming language, that demonstrate grade-appropriate programming concepts and proficiency; and e. implement instructional practices and grade-appropriate applications on the interrelationships between the field of computer science and disparate content areas to: i. make concrete and abstract representations; and ii. connect computer science with real-world situations.
- C. Objective: Students will apply content knowledge of CS on a variety of subdisciplines, programming concepts, and interdisciplinary approaches to enact engaging and motivating learning. 3. Outcome: Students will demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations knowledge of and/or the ability to effectively instruct: a. artificial intelligence; b. computational sciences; c. computer programming; d. cybersecurity; e. data science; f. hardware and network systems; g. machine learning; and h. robotics.
- D. Objective: Students will cultivate K-12 students' CS identities by helping them realize the usefulness of CS by providing connections to students' everyday lives. Build CS self-efficacy by encouraging persistence and demonstrating the belief that every student is capable of learning and expressing their creativity and intelligence with CS. 4. Outcome: Students will demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations knowledge of specific shifts in general instruction practices required for computer science education and the ability to assist K-12 students: a. develop resilience and perseverance with regard to computer science and computational learning experiences; b. attain a level of comfort with ambiguity and open-ended problems; c. see failure as an opportunity to learn and innovate; d. understand that computational thinking is a fundamental human ability and does not require a computer, and how that understanding can leverage the power of computers to solve a problem; e. recognize that not all problems can be solved computationally; and f. understand the role and importance of cybersecurity.
- E. Objective: Students will collaborate with others towards giving and receiving feedback on both oral and written work about teaching CS as a community of inquiry. 5. Outcome: Students shall demonstrate in writing (e.g., lesson plans, reflections, essays) and in teaching presentations the ability to self-assess and act upon feedback regarding the effectiveness of instruction based on the achievement of students.
- F. Objective: Students will develop an appreciation for teaching as a practice which requires ongoing study. 6. Outcome: Students will demonstrate knowledge about pursuing continuous professional

development through appropriate activities, coursework and participation in relevant professional organizations to keep abreast of the ever-changing developments in technology.

CSED564. CAPSTONE CURRICULUM DESIGN I - PRACTICUM. 3.0 Semester Hrs.

This course provides Mines students an intensive teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is an approximately 6 hours per week (100-hours total) field experience requirement in the student?s assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed/concurrent 3 credits of SCED 562; complete/concurrent with CSED 530 or CSED 535. Co-requisite: Completed/concurrent 3 credits of SCED 562; complete/concurrent with CSED 530 or CSED 535.

Course Learning Outcomes

- reflect on their practice and use this reflection to set goals for further growth.
- write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E's (engage, explore, explain, elaborate and evaluate) or other learning cycle model, accommodations, formative assessment and subject integration.
- utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science, engineering or STEM, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- engage in professional behavior expected of new teachers including a. appropriate dress, b. attendance and professional commitments, c. teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), d. respectful collaboration (even if do not agree), e. professional initiative, and f. student confidentiality related to both academic performance and personal lives.
- learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

CSED565. CAPSTONE CURRICULUM DESIGN II - STUDENT TEACHING. 6-12 Semester Hr.

This course provides Mines students an immersive student teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 32-hour per credit hour enrolled field experience requirement in the student?s assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a work sample (unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed CSED 564; completed/concurrent with SCED 533, SCED 563, CSED 530, and CSED 535. Co-requisite: Completed/concurrent with SCED 533, SCED 563, CSED 530, and CSED 535.

Course Learning Outcomes

- utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science, engineering or STEM, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson;

reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.

- apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- engage in professional behavior expected of new teachers including a. appropriate dress, b. attendance and professional commitments, c. teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), d. respectful collaboration (even if do not agree), e. professional initiative, and f. student confidentiality related to both academic performance and personal lives.
- learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

CSED598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Repeatable for credit under different titles.

MAED262. K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS. 1.0 Semester Hr.
This course is designed to provide Mines students with opportunities to participate in, analyze, and reflect on issues in a mathematics or computer science K-12 school classroom setting. The overall goal is for Mines students to understand who their students are, build relationships, and begin exploring learner development and learner differences. Specifically, the course will focus on developing Mines students? ability to identify and practice basic classroom management, differentiate instruction, ask probing questions, mathematics or computer science content preconceptions, language/activities that promote a growth mindset, and professional language. Furthermore, Mines students will begin exploring the factors that shape school norms and culture. In addition to an on-campus seminar, there is a 25-hour field experience requirement in the student?s assigned partner school.
Course Learning Outcomes

- • identify and provide examples of differentiated instruction.
- • identify and provide examples of formative-assessment techniques used to evaluate what students are thinking during classroom activities
- • articulate the value of reflecting on their practice.
- • explain different levels of questioning and how to ask probing questions as well as provide examples of how to use these types of questioning.
- • articulate reasons for, ways to, and examples of how they built relationships with each and every student in their classroom.
- • articulate and document the mathematics or computer science content specific preconceptions that they observed students demonstrate during the field placement.
- • identify the school policies and practices of their field placement.
- • identify factors that shaped the culture and norms of the school they experienced.
- • communicate effectively, model appropriate use of language (e.g., use of proper grammar, use of professional language, and use of discipline-specific vocabulary), and identify unprofessional language.
- • articulate the critical role of high ethical standards, including a belief in being committed to displaying ethical conduct towards students, performance and the profession, colleagues, and parents and the community.
- • recognize that with quality instruction and hard work, all students are capable of learning science and mathematics; use language, activities and feedback that is consistent with a growth mindset.

MAED405. MATHEMATICAL PRACTICES AND THE SOCIAL CONTEXT OF MATHEMATICS. 3.0 Semester Hrs.
This course provides teacher candidates an opportunity to develop the skills to promote students mathematical identity and their understanding of mathematical practices and processes - mathematics is a community of inquiry-as articulated in the Colorado Academic Standards and Common Core. These skills will be modeled, practiced and mastered in the context of authentic mathematical practices (eg. the formation of the quadratic equation through maximization of orange production). Teacher candidates will engage as learners, reflect as practitioners, and finally develop their own 3-day mini-unit. To promote candidates awareness of the social context of mathematics, candidates will explore the historical development of content and perspectives from diverse cultures. In addition this course will prepare students to be able to communicate effectively in a variety of mediums (written, oral, and digital) as educators about mathematical processes and practices.
Course Learning Outcomes

- nurture development of mathematical processes and practices. They anticipate how students' use of mathematical practices will look and sound within specific grade-band mathematical topics, knowing that over years of experience, their knowledge of students' ways of using mathematical practices will expand to more mathematical topics.
- identify, adapt, or develop lessons that explicitly teach mathematical process and practices demonstrating these as tools use to solve problems and communicate ideas.
- demonstrate that doing mathematics is a sense-making activity that promotes perseverance, problem posing, and problem solving.
- provide examples and connections for students to see that mathematics is a human endeavor that is practice in and out of school, across many facets of life.
- integrate the history of mathematics into content and share contributions from people with different gender and cultural, linguistic, religious, and racial/ethnic backgrounds.
- articulate how mathematics is based on constructed conventions and agreements about the meanings of words and symbols, and these conventions vary; algorithms considered as standard in the United States different from algorithms used in other countries.

- cultivate their students' mathematical identity by helping students realize the usefulness of mathematics by providing connections to students' everyday lives and building their students mathematics self-efficacy by encouraging hard work from every student and demonstrating the belief that every student is capable of learning and using mathematics
- identify and implement practices that draw on students' mathematical, cultural, and linguistic resources/strengths and challenge practices grounded in deficit-based thinking.
- select, adapt, or develop lessons that explicitly engage students the mathematical practices defined in the Colorado Academic Standards and Common Core in mathematics.
- identify, adapt, or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations.
- create a mini-unit (3 days or more) that explicitly teaches some aspect of mathematical practices or the social context of mathematics.
- • clearly articulate their mathematical ideas in writing. o analyze text based on occasion, audience, form and function. o compose one page reflections with an awareness about introductions, conclusions and topic sentences. o articulate the process of and compose with an awareness about the composing process which is an iterative process of formulation, composition and revision. o incorporate and cite correctly all evidence used to support a text's claim/s.
- • clearly articulate their mathematical ideas verbally. o delineate effective characteristics of multi-media presentations. o articulate mathematical practices in a way that secondary students can understand and be motivated to explore these practices. o collaborate with others towards giving and receiving feedback on both oral and written work about teaching mathematics as a community of inquiry.

MAED425. PRE-ALGEBRA AND ALGEBRA TEACHING TECHNIQUES. 3.0 Semester Hrs.

In this course teacher candidates will be exposed to evidence-based instructional practices to support students learning of pre-algebra and algebra and model meaningful learning opportunities, common misconceptions and ways of thinking, and students learning progressions (i.e., content trajectory). The goal of this course is for teacher candidates is to develop an awareness of 1) the common misconceptions and learning progressions associated with pre-algebra and algebra; 2) students learning progressions in pre-algebra and algebra, and 3) evidence-based and meaningful instructional strategies for pre-algebra and algebra. The teacher candidate analyzes conceptual algebra underpinnings, common misconceptions, and students' ways of thinking to create opportunities to learn.

Course Learning Outcomes

- • plan at least the first month of instruction for a middle or high school pre-algebra or algebra course using standards-based lessons experienced in this course.
- • construct and evaluate mathematical conjectures and argument to validate one's own mathematical thinking.
- • identify and develop lessons that are designed to build students knowledge as defined in the Colorado Academic Standards in mathematics and literacy. Candidates will be able to
- • articulate the scope of the above standards related to the content knowledge necessary for teaching 7-12 students.
- • describe mathematical ideas, using every day and mathematical language, in both verbal and written formats.

MAED464. CAPSTONE CURRICULUM DESIGN I. 6-12 Semester Hr.

This course provides Mines students an intensive teaching experience in a K-12 mathematics or computer science classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 100-hour field experience requirement in the students assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed/concurrent 3 credits of SCED 262; completed/concurrent with MAED 405 or MAED 425. Corequisite: Completed/concurrent 3 credits of SCED 262; completed/concurrent with MAED 405 or MAED 425.

Course Learning Outcomes

- • utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- • identify, adapt, or develop lessons using a core set of pedagogical practices that are effective for developing students' meaningful learning of mathematics which include establishing goals, promoting reasoning and problem solving, connecting mathematical representations, meaningful discourse, purposeful questions, procedural fluency based on conceptual understanding, and productive struggle. While planning lessons program completers will also anticipate and attend to students' prior knowledge, problem solving approaches, mathematical practices, dispositions, mathematical identity, and mathematical communication.
- • use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- • identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- • engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments,

o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.

- • learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- • provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.
- • reflect on their practice and use this reflection to set goals for further growth.
- • write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E's (engage, explore, explain, elaborate and evaluate) or other learning cycle model, accommodations, formative assessment and subject integration.

MAED465. CAPSTONE CURRICULUM DESIGN II. 6-12 Semester Hr.
This course provides Mines students an intensive teaching experience in a K-12 mathematics or computer science classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 32-hour per credit hour enrolled field experience requirement in the students assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed MAED 464; completed/concurrent with SCED 333, SCED 363, MAED 405, and MAED 425. Corequisite: Completed/concurrent with SCED 333, SCED 363, MAED 405, and MAED 425.
Course Learning Outcomes

- • utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- • identify, adapt, or develop lessons using a core set of pedagogical practices that are effective for developing students' meaningful learning of mathematics or computer science which include establishing goals, promoting reasoning and problem solving, connecting mathematical representations, meaningful discourse, purposeful questions, procedural fluency based on conceptual understanding, and productive struggle. While planning lessons program completers will also anticipate and attend to students' prior knowledge, problem solving approaches, mathematical practices, dispositions, mathematical identity, and mathematical communication.
- • use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- • identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- • engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- • learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- • provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

MAED505. MATHEMATICAL PRACTICES AND THE SOCIAL CONTEXT OF MATHEMATICS. 3.0 Semester Hrs.
n/a.
Course Learning Outcomes

- nurture development of mathematical processes and practices. They anticipate how students' use of mathematical practices will look and sound within specific grade-band mathematical topics, knowing that over years of experience, their knowledge of students' ways of using mathematical practices will expand to more mathematical topics.
- identify, adapt, or develop lessons that explicitly teach mathematical process and practices demonstrating these as tools use to solve problems and communicate ideas.
- demonstrate that doing mathematics is a sense-making activity that promotes perseverance, problem posing, and problem solving.
- provide examples and connections for students to see that mathematics is a human endeavor that is practice in and out of school, across many facets of life.
- integrate the history of mathematics into content and share contributions from people with different gender and cultural, linguistic, religious, and racial/ethnic backgrounds.
- articulate how mathematics is based on constructed conventions and agreements about the meanings of words and symbols, and these

conventions vary; algorithms considered as standard in the United States different from algorithms used in other countries.

- cultivate their students’ mathematical identity by helping students realize the usefulness of mathematics by providing connections to students’ everyday lives and building their students mathematics self-efficacy by encouraging hard work from every student and demonstrating the belief that every student is capable of learning and using mathematics
- identify and implement practices that draw on students’ mathematical, cultural, and linguistic resources/strengths and challenge practices grounded in deficit-based thinking.
- select, adapt, or develop lessons that explicitly engage students the mathematical practices defined in the Colorado Academic Standards and Common Core in mathematics.
- identify, adapt, or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations.
- create a mini-unit (3 days or more) that explicitly teaches some aspect of mathematical practices or the social context of mathematics.
- clearly articulate their mathematical ideas in writing. o analyze text based on occasion, audience, form and function. o compose one page reflections with an awareness about introductions, conclusions and topic sentences. o articulate the process of and compose with an awareness about the composing process which is an iterative process of formulation, composition and revision. o incorporate and cite correctly all evidence used to support a text’s claim/s.
- clearly articulate their mathematical ideas verbally. o delineate effective characteristics of multi-media presentations. o articulate mathematical practices in a way that secondary students can understand and be motivated to explore these practices. o collaborate with others towards giving and receiving feedback on both oral and written work about teaching mathematics as a community of inquiry.

MAED525. PRE-ALGEBRA AND ALGEBRA TEACHING TECHNIQUES. 3.0 Semester Hrs.

In this course teacher candidates will be exposed to evidence-based instructional practices to support students? learning of pre-algebra and algebra and model meaningful learning opportunities, common misconceptions and ways of thinking, and students? learning progressions (i.e., content trajectory). The goal of this course is for teacher candidates is to develop an awareness of 1) the common misconceptions and learning progressions associated with pre-algebra and algebra; 2) students learning progressions in pre-algebra and algebra, and 3) evidence-based and meaningful instructional strategies for pre-algebra and algebra. The teacher candidate analyzes conceptual algebra underpinnings, common misconceptions, and students' ways of thinking to create opportunities to learn.

Course Learning Outcomes

- plan at least the first month of instruction for a middle or high school pre-algebra or algebra course using standards-based lessons experienced in this course.
- construct and evaluate mathematical conjectures and argument to validate one’s own mathematical thinking.
- identify and develop lessons that are designed to build students knowledge as defined in the Colorado Academic Standards in mathematics and literacy. Candidates will be able to articulate the scope of the above standards related to the content knowledge necessary for teaching 7-12 students.
- describe mathematical ideas, using every day and mathematical language, in both verbal and written formats.

MAED562. K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS. 1-3 Semester Hr.

This course is designed to provide Mines students with opportunities to participate in, analyze, and reflect on issues in a mathematics or computer science K-12 school classroom setting. The overall goal is for Mines students to understand who their students are, build relationships, and begin exploring learner development and learner differences. Specifically, the course will focus on developing Mines students? ability to identify and practice basic classroom management, differentiate instruction, ask probing questions, mathematics or computer science content preconceptions, language/activities that promote a growth mindset, and professional language. Furthermore, Mines students will begin exploring the factors that shape school norms and culture. In addition to an on-campus seminar, there is a 25-hour field experience requirement in the student?s assigned partner school.

Course Learning Outcomes

- identify and provide examples of differentiated instruction.
- identify and provide examples of formative-assessment techniques used to evaluate what students are thinking during classroom activities
- articulate the value of reflecting on their practice.
- explain different levels of questioning and how to ask probing questions as well as provide examples of how to use these types of questioning.
- articulate reasons for, ways to, and examples of how they built relationships with each and every student in their classroom.
- articulate and document the mathematics or computer science content specific preconceptions that they observed students demonstrate during the field placement.
- identify the school policies and practices of their field placement.
- identify factors that shaped the culture and norms of the school they experienced.
- communicate effectively, model appropriate use of language (e.g., use of proper grammar, use of professional language, and use of discipline-specific vocabulary), and identify unprofessional language.
- articulate the critical role of high ethical standards, including a belief in being committed to displaying ethical conduct towards students, performance and the profession, colleagues, and parents and the community.
- recognize that with quality instruction and hard work, all students are capable of learning science and mathematics; use language, activities and feedback that is consistent with a growth mindset.

MAED564. CAPSTONE CURRICULUM DESIGN I. 3.0 Semester Hrs.

This course provides Mines students an intensive teaching experience in a K-12 mathematics or computer science classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is an approximately 6 hours per week (100-hours total) field experience requirement in the student?s assigned partner school. During this semester, the student will be responsible for planning

and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection).. Prerequisites: Completed/concurrent 3 credits of SCED 562; completed/concurrent with MAED 505 or MAED 525. Corequisites: Completed/concurrent 3 credits of SCED 562; completed/concurrent with MAED 505 or MAED 525.
Course Learning Outcomes

- utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- identify, adapt, or develop lessons using a core set of pedagogical practices that are effective for developing students’ meaningful learning of mathematics which include establishing goals, promoting reasoning and problem solving, connecting mathematical representations, meaningful discourse, purposeful questions, procedural fluency based on conceptual understanding, and productive struggle. While planning lessons program completers will also anticipate and attend to students’ prior knowledge, problem solving approaches, mathematical practices, dispositions, mathematical identity, and mathematical communication.
- use formative-assessment techniques (10 or more) to evaluate students’ thinking during classroom activities and assess students’ progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- identify lessons that are well designed to build students’ reading, writing, speaking and listening with science or mathematics classes.
- engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student’s teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school’s teachers, administrators, parents, students and community in which it is situated.
- provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.
- reflect on their practice and use this reflection to set goals for further growth.
- write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E’s (engage, explore, explain, elaborate and evaluate) or other learning cycle model, accommodations, formative assessment and subject integration.

MAED565. CAPSTONE CURRICULUM DESIGN II. 6-12 Semester Hr.
This course provides Mines students an intensive teaching experience in a K-12 mathematics or computer science classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 2 hours per week (32-hours total) per credit hour enrolled field experience requirement in the student?s assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisites: Completed MAED 564; completed/concurrent with SCED 333, SCED 363, MAED 505, and MAED 425. Corequisites: Completed/concurrent with SCED 333, SCED 363, MAED 505, and MAED 425.
Course Learning Outcomes

- utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- identify, adapt, or develop lessons using a core set of pedagogical practices that are effective for developing students’ meaningful learning of mathematics or computer science which include establishing goals, promoting reasoning and problem solving, connecting mathematical representations, meaningful discourse, purposeful questions, procedural fluency based on conceptual understanding, and productive struggle. While planning lessons program completers will also anticipate and attend to students’ prior knowledge, problem solving approaches, mathematical practices, dispositions, mathematical identity, and mathematical communication.
- use formative-assessment techniques (10 or more) to evaluate students’ thinking during classroom activities and assess students’ progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to

create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).

- create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

SCED262. K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS. 1-3 Semester Hr.

This course is designed to provide Mines students with opportunities to participate in, analyze, and reflect on issues in a science K-12 school classroom setting. The overall goal is for Mines students to understand who their students are, build relationships, and begin exploring learner development and learner differences. Specifically, the course will focus on developing Mines students ability to identify and practice basic classroom management, differentiate instruction, ask probing questions, science content preconceptions, language/activities that promote a growth mindset, and professional language. Furthermore, Mines students will begin exploring the factors that shape school norms and culture. In addition to an on-campus seminar, there is a 25-hour field experience requirement in the students assigned partner school.

Course Learning Outcomes

- • identify and provide examples of differentiated instruction.
- • identify and provide examples of formative-assessment techniques used to evaluate what students are thinking during classroom activities
- • articulate the value of reflecting on their practice.
- • explain different levels of questioning and how to ask probing questions as well as provide examples of how to use these types of questioning.
- • articulate reasons for, ways to, and examples of how they built relationships with each and every student in their classroom.
- • articulate and document the science content specific preconceptions that they observed students demonstrate during the field placement.
- • identify the school policies and practices of their field placement.
- • identify factors that shaped the culture and norms of the school they experienced.
- • communicate effectively, model appropriate use of language (e.g., use of proper grammar, use of professional language, and use of discipline-specific vocabulary), and identify unprofessional language.
- • articulate the critical role of high ethical standards, including a belief in being committed to displaying ethical conduct towards students, performance and the profession, colleagues, and parents and the community.
- • recognize that with quality instruction and hard work, all students are capable of learning science and mathematics; use language, activities and feedback that is consistent with a growth mindset.

SCED333. EDUCATIONAL PSYCHOLOGY AND ASSESSMENT. 3.0 Semester Hrs.

An explosive growth in research on how people learn has revealed many ways to improve teaching and catalyze learning at all ages. The purpose of this course is to present this new science of learning so that educators can creatively translate the science into exceptional practice. This course covers field-defining learning theories ranging from behaviorism to cognitive psychology to social psychology and some lesser-known theories exceptionally relevant to practice, such as arousal theory. Together the theories, evidence, and strategies can be combined endlessly to create original and effective learning plans and the means to know if they succeed.

Course Learning Outcomes

- • Describe in general what cognitive science has learned about how the brain works related to the topics of conceptual understanding, memory, motivation, expertise, study skills, sense of inclusion, problem solving, collaboration, and discovery.
- • Analyze various effective teaching practices in math and the sciences and provide examples of how the above topics in cognitive science inform these practices.
- • utilize research based methods of instruction that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, repeatedly alternating solved and unsolved problems, distributed practice, and assessment to boost retention.
- • effectively integrate technology into instructional and assessment strategies, as appropriate to science and mathematical education and the learner including but not limited to the use of a variety of resources (e.g., manipulative materials, graphing calculators, every-day hands-on materials, probe ware, and computers).
- •Explain the value of embedding disciplinary research into the high school classroom and provide an example in science or math of how this can be done.
- •• Define data driven instruction, brain plasticity, and individual differences.
- • Utilize formative assessment daily to adjust to students' needs as they are teaching and to determine where instruction can be improved next time.
- • Utilize pre/post-tests as a form of formative assessment on a unit basis to determine change, learning gains, and effect size by group; Then, use the results to modify their future instruction.
- • Use summative assessment to determine student level of mastery
- • Provide accurate information about the teaching profession related to salary, benefits, and teacher satisfaction.
- • Provide evidence for the nations' science and math teacher shortage and describe some research-based actions that can help change the direction of this trend.
- • continuously improve their knowledge and understanding of the ever-changing knowledge base of both content, and science/

mathematics pedagogy, including approaches for addressing inequities and inclusion for all students in science and math.

SCED363. DYNAMIC TEACHING: MOTIVATION, CLASSROOM MANAGEMENT, AND DIFFERENTIATION OF INSTRUCTION. 3.0 Semester Hrs.

Effective teaching is a dynamic process that requires the instructor to motivate, manage, and vary instruction for all learners in the classroom. The purpose of this course is to prepare future educators to be able to motivate students, manage classroom behavior, and differentiate their instruction so that all students can learn. This course will cover the field-defining theories of motivation, classroom management, and differentiation. Additionally, this course will introduce research-based practices that can be used to create learning environments where students are motivated and given the tools to be successful in their individual learning.

Course Learning Outcomes

- • Describe theories of motivation and how classroom practices connect to those theories.
- • Describe classroom management theories and how practices connect to those theories.
- • Describe how differentiation techniques can be used to assist students with various exceptionalities.
- • Create effective lesson plans that differentiate instruction for students in a classroom.
- • Evaluate learning environments to recognize effective and ineffective motivation, management, and differentiation techniques in practice.
- • cultivate students' scientific/mathematics identify and confidence in learning science/math by connecting their instruction and content to students' background, providing ample opportunities for students to experience and reflect on success in learning science/mathematics content and practices, making their instruction and content relevant to students' lives, and helping students to contextualize the information being taught.
- • use classroom management, motivation, and differentiation practices to plan for and set the conditions of an effective learning environment.
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • demonstrate a commitment to and respect for diversity, while working toward common goals as a community and as a country.

SCED398. SPECIAL TOPICS. 6.0 Semester Hrs.

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

SCED415. SCIENTIFIC PRACTICES VS ENGINEERING DESIGN AND THE NATURE OF SCIENCE. 3.0 Semester Hrs.

The goal of this course is to prepare students to integrate knowledge of scientific and engineering practices into their teaching as articulated in the Colorado Academic Standards and the Next Generation Science Standards, including asking questions, defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, obtaining, evaluating and communicating information. These skills will be modeled, practiced and mastered in the context of science, specifically: 1) earthquakes and waves, 2) mitosis, meiosis, and reproduction, 4) periodic table of the elements, 5) energy conservation, and 6) forces in static equilibrium. In addition this course will prepare students to be able to communicate effectively in a variety of mediums (written, oral, and digital) as educators about scientific and engineering practices.

Course Learning Outcomes

- 1. engage in appropriate scientific practices and support their students in doing the same.
- 2. identify, adapt or develop lessons specifically designed to engage students in scientific and engineering practices, including but not limited to, asking questions (for science) and defining problems (for engineering); analyzing and interpreting data; engaging in argument from evidence; constructing explanations (for science) and designing solutions (for engineering); developing and using models; planning and carrying out investigations; obtaining, evaluating, and communicating information; and using mathematics and computational thinking. o compare and contrast "Scientific Practice" with "Engineering Design" o judge a student's abilities to do design practices in an informed way. o describe an engineering design cycle and how to apply it to design challenges o define and provide examples of design criteria and design constraints
- 3. effectively instruct students about and model the basic understandings about the nature of science: science as a way of knowing, scientists use a variety of methods, science is based on evidence, science is open to revision, scientists use models, laws, mechanisms, and theories, science assumes order and consistency in natural systems, science is a human endeavor, and science addresses questions about the natural and material world. o articulate how scientific knowledge is acquired in a way that secondary students can comprehend. o describe the practices that brought about at least one major breakthrough in each of the four primary disciplines of science and how this contributed to our modern understanding of science. o analyze differences in the process of scientific discovery as described in the course text. o formulate a generalization and assess the evidence used to support a generalization or scientific theory. o provide examples that demonstrate the necessity for observations and characterization of patterns to understand the invisible.
- 4. integrate current issues and events related to science, and age-/grade-appropriate controversial topics presented from multiple science perspectives into lessons using an analytical approach without bias.
- 5. select, adapt, or develop lessons that explicitly engage students in scientific and engineering practices defined by the Colorado Academic Standards in science, and the Next Generation Science Standards (NGSS).
- 6. identify, adapt or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations; for example through cross-cutting concepts defined in NGSS.
- 7. illustrate the value of a model in understanding composition and in science.
- 8. create a mini-unit (3 days or more) that explicitly teaches some aspect of scientific or engineering practice.
- 9. clearly articulate their scientific ideas in writing. o analyze text based on occasion, audience, form and function. o compose one page reflections with an awareness about introductions, conclusions

and topic sentences. o articulate the process of and compose with an awareness about the composing process which is an iterative process of formulation, composition and revision. o incorporate and cite correctly all evidence used to support a text's claim/s.

- 10. clearly articulate their scientific ideas verbally. o delineate effective characteristics of multi-media presentations. o articulate scientific practices in a way that secondary students can understand and be motivated to explore these practices. o collaborate with others towards giving and receiving feedback on both oral and written work about teaching science as a way of knowing.

SCED445. PHYSICS AND CHEMISTRY TEACHING TECHNIQUES. 3.0 Semester Hrs.
In this course students will engage as learners of physics and chemistry through evidence-based teaching strategies. After each unit of instruction, students will reflect on the practices used during the unit and why these practices are effective techniques for teaching science. The goal of this course is for teacher candidates to develop an awareness of 1) the common misconceptions and learning progressions associated with physics and chemistry; 2) evidence-based teaching strategies for physics and chemistry; and 3) the importance of and techniques for placing all content within a context that is familiar to and interesting to your specific student body. Students will leave this course with a minimum of a full month of curriculum annotated and ready to deliver to middle or high school physical science and high school physics courses.
Course Learning Outcomes

- • plan at least the first month of instruction for a middle or high school physics or chemistry course using standards-based lessons experienced in this course.
- • identify lessons that are designed to build students knowledge as defined in the Colorado Academic Standards in science, mathematics, and literacy and the Next Generation Science Standards (NGSS),
- • articulate and offer recommendations for addressing the common student preconceptions associated with all of the topics listed above for physical science and physics.
- • integrate content within identified student personal interest to build student engagement and connections to the world around them.
- • utilize Just in Time Teaching to plan lessons that meet students current interests and background knowledge.
- • articulate the scope of the above standards related to the content knowledge necessary for teaching 7-12 students.
- • articulate and engage students in investigation of the major concepts, principles, theories, laws, and interrelationships in science that underlie what they encounter in teaching.

SCED464. CAPSTONE CURRICULUM DESIGN I. 3.0 Semester Hrs.
This course provides Mines students an intensive teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 100-hour field experience requirement in the students assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed/concurrent 3 credits of SCED 262; completed/concurrent with SCED 415 or SCED 445. Co-requisite: Completed/concurrent 3 credits of SCED 262; completed/concurrent with SCED 415 or SCED 445.
Course Learning Outcomes

- • utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- • identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- • use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- • identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- • engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- • learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- • provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.
- • reflect on their practice and use this reflection to set goals for further growth.
- • write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E's (engage, explore, explain, elaborate and evaluate) or

other learning cycle model, accommodations, formative assessment and subject integration.

SCED465. CAPSTONE CURRICULUM DESIGN II. 6-12 Semester Hr.
This course provides Mines students an immersive student teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 32-hour per credit hour enrolled field experience requirement in the students assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a work sample (unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed SCED 464; completed/concurrent with SCED 333, SCED 363, SCED 415, and SCED 445. Corequisites: Completed/concurrent with SCED 333, SCED 363, SCED 415, and SCED 445.
Course Learning Outcomes

- • utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- • identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science or engineering, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- • use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- • apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- • create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- • identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- • engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- • learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- • provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

SCED515. SCIENTIFIC PRACTICES VS ENGINEERING DESIGN AND THE NATURE OF SCIENTIFIC KNOWLEDGE. 3.0 Semester Hrs.
The goal of this course is to prepare students to integrate knowledge of scientific and engineering practices into their teaching as articulated in the Colorado Academic Standards and the Next Generation Science Standards, including asking questions, defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, obtaining, evaluating and communicating information. These skills will be modeled, practiced and mastered in the context of science, specifically: 1) earthquakes and waves, 2) mitosis, meiosis, and reproduction, 4) periodic table of the elements, 5) energy conservation, and 6) forces in static equilibrium. In addition this course will prepare students to be able to communicate effectively in a variety of mediums (written, oral, and digital) as educators about scientific and engineering practices.
Course Learning Outcomes

- 1. engage in appropriate scientific practices and support their students in doing the same.
- 2. identify, adapt or develop lessons specifically designed to engage students in scientific and engineering practices, including but not limited to, asking questions (for science) and defining problems (for engineering); analyzing and interpreting data; engaging in argument from evidence; constructing explanations (for science) and designing solutions (for engineering); developing and using models; planning and carrying out investigations; obtaining, evaluating, and communicating information; and using mathematics and computational thinking. o compare and contrast "Scientific Practice" with "Engineering Design" o judge a student's abilities to do design practices in an informed way. o describe an engineering design cycle and how to apply it to design challenges o define and provide examples of design criteria and design constraints compare and contrast "Scientific Practice" with "Engineering Design"; judge a student's abilities to do design practices in an informed way; describe an engineering design cycle and how to apply it to design challenges; define and provide examples of design criteria and design constraints
- 3. effectively instruct students about and model the basic understandings about the nature of science: science as a way of knowing, scientists use a variety of methods, science is based on evidence, science is open to revision, scientists use models, laws, mechanisms, and theories, science assumes order and consistency in natural systems, science is a human endeavor, and science addresses questions about the natural and material world. o articulate how scientific knowledge is acquired in a way that secondary students can comprehend. o describe the practices that brought about at least one major breakthrough in each of the four primary disciplines of science and how this contributed

to our modern understanding of science. o analyze differences in the process of scientific discovery as described in the course text. o formulate a generalization and assess the evidence used to support a generalization or scientific theory. o provide examples that demonstrate the necessity for observations and characterization of patterns to understand the invisible.

- 4. integrate current issues and events related to science, and age-/grade-appropriate controversial topics presented from multiple science perspectives into lessons using an analytical approach without bias.
- 5. select, adapt, or develop lessons that explicitly engage students in scientific and engineering practices defined by the Colorado Academic Standards in science, and the Next Generation Science Standards (NGSS).
- 6. identify, adapt or develop lessons that reflect the interconnectedness of content areas/disciplines to help erase the disciplinary lines and reflect authentic situations; for example through cross-cutting concepts defined in NGSS.
- 7. illustrate the value of a model in understanding composition and in science.
- 8. create a mini-unit (3 days or more) that explicitly teaches some aspect of scientific or engineering practice.
- 9. clearly articulate their scientific ideas in writing. o analyze text based on occasion, audience, form and function. o compose one page reflections with an awareness about introductions, conclusions and topic sentences. o articulate the process of and compose with an awareness about the composing process which is an iterative process of formulation, composition and revision. o incorporate and cite correctly all evidence used to support a text's claims.
- 10. clearly articulate their scientific ideas verbally. o delineate effective characteristics of multi-media presentations. o articulate scientific practices in a way that secondary students can understand and be motivated to explore these practices. o collaborate with others towards giving and receiving feedback on both oral and written work about teaching science as a way of knowing.

SCED533. EDUCATIONAL PSYCHOLOGY AND ASSESSMENT. 3.0 Semester Hrs.

An explosive growth in research on how people learn has revealed many ways to improve teaching and catalyze learning at all ages. The purpose of this course is to present this new science of learning so that educators can creatively translate the science into exceptional practice. This course covers field-defining learning theories ranging from behaviorism to cognitive psychology to social psychology and some lesser-known theories exceptionally relevant to practice, such as arousal theory. Together the theories, evidence, and strategies can be combined endlessly to create original and effective learning plans and the means to know if they succeed.

Course Learning Outcomes

- Describe in general what cognitive science has learned about how the brain works related to the topics of conceptual understanding, memory, motivation, expertise, study skills, sense of inclusion, problem solving, collaboration, and discovery.
- Analyze various effective teaching practices in math and the sciences and provide examples of how the above topics in cognitive science inform these practices.
- utilize research based methods of instruction that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, repeatedly alternating solved and unsolved problems, distributed practice, and assessment to boost retention.
- effectively integrate technology into instructional and assessment strategies, as appropriate to science and mathematical education and the learner including but not limited to the use of a variety of resources (e.g., manipulative materials, graphing calculators, every-day hands-on materials, probe ware, and computers).
- Explain the value of embedding disciplinary research into the high school classroom and provide an example in science or math of how this can be done.
- Define data driven instruction, brain plasticity, and individual differences.
- Utilize formative assessment daily to adjust to students' needs as they are teaching and to determine where instruction can be improved next time.
- Utilize pre/post-tests as a form of formative assessment on a unit basis to determine change, learning gains, and effect size by group; Then, use the results to modify their future instruction.
- Use summative assessment to determine student level of mastery
- Provide accurate information about the teaching profession related to salary, benefits, and teacher satisfaction.
- Provide evidence for the nations' science and math teacher shortage and describe some research-based actions that can help change the direction of this trend.
- continuously improve their knowledge and understanding of the ever-changing knowledge base of both content, and science/mathematics pedagogy, including approaches for addressing inequities and inclusion for all students in science and math.

SCED545. PHYSICS AND CHEMISTRY TEACHING TECHNIQUES. 3.0 Semester Hrs.

In this course students will engage as learners of physics and chemistry through evidence-based teaching strategies. After each unit of instruction, students will reflect on the practices used during the unit and why these practices are effective techniques for teaching science. The goal of this course is for teacher candidates to develop an awareness of 1) the common misconceptions and learning progressions associated with physics and chemistry; 2) evidence-based teaching strategies for physics and chemistry; and 3) the importance of and techniques for placing all content within a context that is familiar to and interesting to your specific student body. Students will leave this course with a minimum of a full month of curriculum annotated and ready to deliver to middle or high school physical science and high school physics courses.

Course Learning Outcomes

- Plan at least the first month of instruction for a middle or high school physics or chemistry course using standards-based lessons experienced in this course.
- Identify lessons that are designed to build students knowledge as defined in the Colorado Academic Standards in science, mathematics, and literacy and the Next Generation Science Standards (NGSS)
- Articulate and offer recommendations for addressing the common student preconceptions associated with all of the topics listed above for physical science and physics.
- Integrate content within identified student personal interest to build student engagement and connections to the world around them.
- Utilize Just in Time Teaching to plan lessons that meet students current interests and background knowledge.

- Articulate the scope of the above standards related to the content knowledge necessary for teaching 7-12 students.
- Articulate and engage students in investigation of the major concepts, principles, theories, laws, and interrelationships in science that underlie what they encounter in teaching.

SCED562. K-12 FIELD EXPERIENCE AND BUILDING STUDENT RELATIONSHIPS. 1-3 Semester Hr.

This course is designed to provide Mines students with opportunities to participate in, analyze, and reflect on issues in a science K-12 school classroom setting. The overall goal is for Mines students to understand who their students are, build relationships, and begin exploring learner development and learner differences. Specifically, the course will focus on developing Mines students? ability to identify and practice basic classroom management, differentiate instruction, ask probing questions, science content preconceptions, language/activities that promote a growth mindset, and professional language. Furthermore, Mines students will begin exploring the factors that shape school norms and culture. In addition to an on-campus seminar, there is a 25-hour field experience requirement in the student?s assigned partner school.

Course Learning Outcomes

- Identify and provide examples of differentiated instruction.
- Identify and provide examples of formative-assessment techniques used to evaluate what students are thinking during classroom activities
- Articulate the value of reflecting on their practice.
- Explain different levels of questioning and how to ask probing questions as well as provide examples of how to use these types of questioning.
- Articulate reasons for, ways to, and examples of how they built relationships with each and every student in their classroom.
- Articulate and document the science content specific preconceptions that they observed students demonstrate during the field placement.
- Identify the school policies and practices of their field placement.
- Identify factors that shaped the culture and norms of the school they experienced.
- Communicate effectively, model appropriate use of language (e.g., use of proper grammar, use of professional language, and use of discipline-specific vocabulary), and identify unprofessional language.
- Articulate the critical role of high ethical standards, including a belief in being committed to displaying ethical conduct towards students, performance and the profession, colleagues, and parents and the community.
- Recognize that with quality instruction and hard work, all students are capable of learning science and mathematics; use language, activities and feedback that is consistent with a growth mindset.

SCED563. DYNAMIC TEACHING: MOTIVATION, CLASSROOM MANAGEMENT, AND DIFFERENTIATION OF INSTRUCTION. 3.0 Semester Hrs.

Effective teaching is a dynamic process that requires the instructor to motivate, manage, and vary instruction for all learners in the classroom. The purpose of this course is to prepare future educators to be able to motivate students, manage classroom behavior, and differentiate their instruction so that all students can learn. This course will cover the field-defining theories of motivation, classroom management, and differentiation. Additionally, this course will introduce research-based practices that can be used to create learning environments where students are motivated and given the tools to be successful in their individual learning.

Course Learning Outcomes

- Describe theories of motivation and how classroom practices connect to those theories.
- Describe classroom management theories and how practices connect to those theories.
- Describe how differentiation techniques can be used to assist students with various exceptionalities.
- Create effective lesson plans that differentiate instruction for students in a classroom.
- Evaluate learning environments to recognize effective and ineffective motivation, management, and differentiation techniques in practice.
- Cultivate students’ scientific/mathematics identify and confidence in learning science/math by connecting their instruction and content to students’ background, providing ample opportunities for students to experience and reflect on success in learning science/mathematics content and practices, making their instruction and content relevant to students’ lives, and helping students to contextualize the information being taught.
- Use classroom management, motivation, and differentiation practices to plan for and set the conditions of an effective learning environment.
- Apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- Demonstrate a commitment to and respect for diversity, while working toward common goals as a community and as a country.

SCED564. CAPSTONE CURRICULUM DESIGN I. 3.0 Semester Hrs.

This course provides Mines students an intensive teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is an approximately 6 hours per week (100-hours total) field experience requirement in the student?s assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction as well as participate in other school related professional roles and will develop a mini-work sample (min-unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisite: Completed/concurrent 3 credits of SCED 562; completed/concurrent with SCED 515 or SCED 545. Co-requisite: Completed/concurrent 3 credits of SCED 562; completed/concurrent with SCED 515 or SCED 545.

Course Learning Outcomes

- Utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- Identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and

identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.

- Use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills
- Apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- Create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- Identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- Engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- Learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- Provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.
- Reflect on their practice and use this reflection to set goals for further growth.
- Write standards-based lesson plans that include measurable learning objectives, applicable Colorado Content Standards, required materials, safety considerations, an outline of the lesson scaffolded with the five E's (engage, explore, explain, elaborate and evaluate) or other learning cycle model, accommodations, formative assessment and subject integration.

SCED565. CAPSTONE CURRICULUM DESIGN II. 6-12 Semester Hr.
This course provides Mines students an immersive student teaching experience in a K-12 science, engineering, or STEM classroom. The goal of this course is for the student to develop and demonstrate competencies in the areas of planning, instructional methods, assessments, creating effective learning environments for all learners, classroom management and organization, content knowledge, and professionalism. In addition to a total of 15 hours of seminars (on campus and teacher professional development), there is a 32-hour per credit hour enrolled field experience requirement in the student's assigned partner school. During this semester, the student will be responsible for planning and teaching at least five periods of classroom instruction for each 3 credit hours enrolled as well as participate in other school related professional roles and will develop a work sample (unit of instruction including: description of setting, learning objectives, three class periods or more of standards-based lesson plans, pre/post assessment, and reflection). Prerequisites: Completed SCED 564; completed/concurrent with SCED 333, SCED 363, SCED 515, and SCED 545. Corequisites: Completed/concurrent with SCED 333, SCED 363, SCED 515, and SCED 545.

Course Learning Outcomes

- Utilize research-based instructional techniques that have been shown to be effective across context, including pairing graphics with words, linking abstract concepts with concrete representations, asking probing questions, repeatedly alternating solved and unsolved problems, distributed practice and assessment to boost retention.
- Identify, adapt, or develop lessons using a variety of active learning techniques based on how all students learn science or engineering, including lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, and identify relationships and natural patterns. Applications of science-specific technology are included in the lessons when appropriate.
- Use formative-assessment techniques (10 or more) to evaluate students' thinking during classroom activities and assess students' progress towards mastery of the learning outcomes in each lesson; reflect on implemented lessons and provide suggestions to improve future implementations to address gaps or needs identified from the formative assessment data, including but not limited to determining appropriate delivery of instruction based on identified student need; and to select appropriate tasks to reinforce and promote students' development of concepts and skills.
- Apply evidence-based classroom management techniques (e.g., establishing rules and routines, utilizing praise and rewards, consistently disciplining misbehavior, and engaging students) to create a positive learning environment (e.g., acceptable learning behaviors and maximizing time on task.).
- Create engaging learning environments that are effective for all students by providing access, support, and challenge for every student as well as differentiating instruction to meet the needs of all students.
- Identify lessons that are well designed to build students' reading, writing, speaking and listening with science or mathematics classes.
- Engage in professional behavior expected of new teachers including o appropriate dress, o attendance and professional commitments, o teacher presence/appropriate boundaries (specifically, can describe the difference between being a student's teacher and being their friend), o respectful collaboration (even if do not agree), o professional initiative, and o student confidentiality related to both academic performance and personal lives.
- Learn about their individual school context, policies and practices and through reflection on prior field experiences have an appreciation for different school cultures and understand that these are shaped by the school's teachers, administrators, parents, students and community in which it is situated.
- Provide proactive, clear and constructive feedback to families about student progress and develop a library of mechanisms to work collaboratively with the families and significant adults in the lives of their students.

Research Professor

Wendy Adams, 2008, University of Colorado, Boulder, Research Professor, Director Teach@Mines

Underground Construction and Tunneling

Programs Offered

Minor in Underground Construction and Tunneling (18 credit hours) and an Area of Special Interest (ASI) (12 credit hours).

Program Educational Objectives

Underground Construction and Tunneling is a growing discipline involving knowledge in the disciplines of mining engineering, geological engineering and civil engineering, among others. The departments of Mining Engineering, Geology and Geological Engineering, and Civil and Environmental Engineering offer an interdisciplinary minor or Area of Special Interest (ASI) course of study that allows students from these departments to take a suite of courses providing them with a basis for work and further study in this field.

The objectives of the minor and ASI are to supplement an engineering background with a formal approach to subsurface engineering that includes site characterization, design and construction of underground infrastructure, including water, storm water, highway or subway tunnels, and subsurface facilities.

The Mines guidelines for Minor/ASI (p. 30) can be found in the Undergraduate Information (p. 14)section of the Mines Catalog (p. 2).

Curriculum

Underground Construction and Tunneling Engineering Minor and ASI

The Underground Construction and Tunneling Engineering minor consists of a minimum of 18 credits of coursework from the list below. An Area of Special Interest (ASI) in Underground Construction and Tunneling requires 12 credits of coursework from the list below. A student's advisor may authorize a student's minor or Area of Special Interest (ASI) application. For questions about the minor and to request consideration of additional courses including independent study, students should meet with a UC&T faculty member. The petition process requires one month to complete. See the following page (p. 30) for CSM's minor and ASI requirements.

Program Requirements:

Required Courses (Minor)

CEEN312	SOIL MECHANICS	3.0
MNGN321	INTRODUCTION TO ROCK MECHANICS	3.0
MNGN404	TUNNELING	3.0

Electives (Minor)

CEEN314	STRUCTURAL ANALYSIS	3.0
CEEN350	CIVIL AND CONSTRUCTION ENGINEERING MATERIALS	3.0
CEEN360	INTRODUCTION TO CONSTRUCTION ENGINEERING	3.0
CEEN499	INDEPENDENT STUDY	1-6
GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN473	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN499	INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY	1-6
MNGN314	UNDERGROUND MINE DESIGN	3.0
MNGN410	EXCAVATION PROJECT MANAGEMENT	2.0
MNGN424	MINE VENTILATION	3.0
MNGN499	INDEPENDENT STUDY	1-6

Program Requirements

Area of Special Interest in Underground Construction and Tunneling:

Required Courses

CEEN312	SOIL MECHANICS	3.0
MNGN321	INTRODUCTION TO ROCK MECHANICS	3.0
MNGN404	TUNNELING	3.0

Electives

Students may choose one course from the required minor courses or elective courses listed above.

Department of Civil & Environmental Engineering

Marte Gutierrez, Professor

Reza Hedayat, Associate Professor

Michael Mooney, Professor

Lori Tunstall, Assistant Professor

Department of Geology & Geological Engineering

Gabriel Walton, Associate Professor

Wendy Zhou, Professor

Department of Mining Engineering

Rennie Kaunda, Assistant Professor

Priscilla Nelson, Professor

Jamal Rostami, Professor

Special Programs

Skills Building Courses

The following courses are offered by various administrative departments on campus to give students the opportunity to build valuable skills to assist with their academic and professional development.

The Freshman Seminar course, CSM101, is a required course and is part of the undergraduate degree requirements. All incoming freshman will be registered for this course during their first semester at Mines. Incoming transfer students may be eligible to receive transfer credit for this course to meet their degree requirements, based on previously completed coursework at the college level.

Transfer students who have successfully completed fewer than 30 transcripted semester hours at an institution of higher education after high school graduation will automatically be enrolled in CSM101.

CSM101	FRESHMAN SUCCESS SEMINAR	1.0
CSM250	ENGINEERING YOUR CAREER PATH	1.0
CSM275	CASA BOUNCE BACK PROGRAM	1.0

For more information about CSM101, contact New Student & Transition Services.

For more information about CSM250, contact the Career Center.

For more information about CSM275, contact the Center for Academic Services and Advising (CASA).

Study Abroad

Spending time abroad is a valuable professional and personal endeavor. Given the worldwide scope and impact of engineering, global competence and intercultural skills are an extremely valuable asset to the workplace and in life. Studying abroad helps you develop and hone these skills. Colorado School of Mines encourages students to include an international study/research/volunteer experience in their undergraduate and/or graduate education.

The Education Abroad division in the Office of Global Education helps students prepare to study abroad from their first initial interest until they return to campus. The Education Abroad team will liaise with the appropriate stakeholders to support the student in applying to a host university abroad, selecting courses, and other pre-departure preparations.

Mines maintains student exchange programs with engineering universities in South America, Europe, Oceania, Africa, and Asia. Courses taken at a partner university abroad can fulfill an equivalent course at Mines if they are pre-approved and successfully passed with a grade of C- or better. Transfer credit is awarded; a student's GPA is not affected by courses taken abroad.

Education Abroad also assists faculty with the development of faculty-led courses abroad during the summer and school breaks.

Financial aid and selected scholarships and grants can be used to finance approved study abroad programs. International university partners may occasionally have additional scholarship funding for study abroad or internship programs. There are a few national study abroad scholarship opportunities available. More information can be found in the Office of Global Education.

Students wishing to pursue study abroad opportunities, either coursework or research, should contact the Office of Global Education in the Green Center, Suite 219. Staff in the office are happy to meet one on one to discuss opportunities abroad. Drop-in times are available each day or students can make an appointment by visiting https://mines.edu/global/.

FIRST-YEAR SEMESTER ABROAD EXPERIENCE

Colorado School of Mines now offers a First-Year Semester Abroad Experience (FYSAE) for incoming students. This innovative experience brings Mines students to Antibes, France, a city along the breathtaking French Riviera. As part of a collaborative and tight-knit cohort, students take STEM-focused courses and humanities that are equivalent to the courses taught on the Golden campus. Students start their undergraduate experience abroad and then seamlessly return to the Mines campus for their second semester.

Experience benefits:

- Participation in a signature experience in Antibes where the Mines cohort joins other students from around the world.
- Take Mines-approved courses that keep students on track toward their degree.
- A full-time resident director will support students throughout the experience, providing guidance, support, and tutoring.
- Explore the French Riviera and surrounding area through organized excursions, volunteer days, culinary workshops, and more.
- Gain intercultural awareness, professional skills and a more inclusive, worldly perspective.
- Participate in pre-departure and re-entry orientations to feel connected to the Mines community.

Experience all of the above for costs similar to studying on the Mines campus (with the exception of flight and visa costs) while staying on track to graduate with a Mines degree.

Writing Across the Curriculum (WAC)

To support the institutional goal of developing professional communication skills, required writing and communication-intensive courses are designated in both the core and in the degree-granting programs. According to guidelines approved by the Undergraduate Council, degree-granting programs are to identify four courses, often two junior- and two senior-level courses as writing-intensive. The (generally four) writing-intensive courses within the various degree-granting programs are designated with (WI) in their course descriptions. Course descriptions can be found on the Undergraduate Programs and Departments page, under the Courses tab for each department.

In addition to disciplinary writing experience, students also obtain writing experience outside their disciplines as courses in HASS are virtually all writing intensive. The Campus Writing Program, housed in the Department of Humanities, Arts, and Social Sciences (HASS), supports the WAC program.

Writing Center

The Writing Center provides free academic support to all members of the campus community, including faculty, staff, students, and alumni. Our consultants can provide assistance with any form of communication including papers, scholarship essays, and presentations at any stage of the process. Writing Center faculty are experienced technical and professional instructors who are experts in a wide variety of fields. The Writing Center is located at 1700 Illinois St. and offers face-to-face and online appointments. Please visit https://writing.mines.edu to learn more about our services. Please reach out to writing@mines.edu or call 303-273-3085 with any questions.

Policies and Procedures

Standards, Codes of Conduct

Students can access campus rules and regulations, including the student code of conduct, alcohol policy, public safety and parking policies, the distribution of literature and free speech policy, and a variety of others by visiting the school's policy website. We encourage all students to review the website and expect that students know and understand the campus policies, rules and regulations as well as their rights as a student. Questions and comments regarding the above-mentioned policies can be directed to the Dean of Students located in the Student Life Office in the Ben Parker Student Center.

For emphasis, the following policies are included or identified in this section:

- Student Honor Code
- Policy on Academic Integrity/Misconduct
- Policy Prohibiting Sexual Harassment, Sexual Violence, and Interpersonal Violence
- Unlawful Discrimination Policy
- Alcohol and Other Drugs Education and Prevention Policy
- Electronic Communications (Email) Policy
- Student Complaint Process
- Access to Student Records
- Posthumous Degree Awards
- Equal Opportunity, Equal Access, and Affirmative Action
    - Office of Institutional Equity & Title IX
    - SpeakUP@Mines

Please note: Any policy or procedure updates during the term will be reflected in the Mines Policy Library and those versions shall control.

Student Honor Code

1.0 PREAMBLE

The students of Colorado School of Mines have adopted the following Student Honor Code in order to establish a high standard of student behavior at Mines. The code may only be amended through a student referendum supported by a majority vote of the Mines student body. Mines students shall be involved in the enforcement of the code through their participation in the Student Conduct Appeals Board.

2.0 CODE

Mines students believe it is our responsibility to promote and maintain high ethical standards in order to ensure our safety, welfare, and enjoyment of a successful learning environment. Each of us, under this code, shall assume responsibility for our behavior in the area of academic integrity. As a Mines student, I am expected to adhere to the highest standards of academic excellence and personal integrity regarding my schoolwork, exams, academic projects, and research endeavors. I will act honestly, responsibly, and above all, with honor and integrity in all aspects of my academic endeavors at Mines. I will not misrepresent the work of others as my own, nor will I give or receive unauthorized assistance in the performance of academic coursework. I will conduct myself in an ethical manner in my use of the library, computing center, and all other school facilities and resources. By practicing these principles, I will strive to uphold the principles of integrity and academic excellence at Mines. I will not participate in or tolerate any form of discrimination or mistreatment of another individual.

Policy on Academic Integrity/Misconduct

1.0 ACADEMIC INTEGRITY

Colorado School of Mines (Mines) affirms the principle that all individuals associated with the Mines academic community have a responsibility for establishing, maintaining, and fostering an understanding and appreciation for academic integrity. In broad terms, this implies protecting the environment of mutual trust within which scholarly exchange occurs, supporting the ability of the faculty to fairly and effectively evaluate every student's academic achievements, and giving credence to the university's educational mission, its scholarly objectives, and the substance of the degrees it awards. The protection of academic integrity requires there to be clear and consistent standards, as well as confrontation and sanctions when individuals violate those standards. Colorado School of Mines desires an environment free of any and all forms of academic misconduct and expects students to act with integrity at all times.

2.0 POLICY ON ACADEMIC MISCONDUCT

Student academic misconduct arises when a student violates the principle of academic integrity and/or when a student aids and abets in the commission of academic misconduct. Academic misconduct may also occur when a student is negligent in their reasonable responsibilities as a student to be aware of or proactively confirm or clarify appropriate conduct with coursework, assignments or exams, and subsequently proceeds in a manner befitting of misconduct. Such behavior erodes mutual trust, distorts the fair evaluation of academic achievements, violates the ethical code of behavior upon which education and scholarship rest, and undermines the credibility of the university.

Because of the serious institutional and individual ramifications, student misconduct arising from violations of academic integrity is not tolerated at Mines. If a student is found to have engaged in such misconduct sanctions such as change of a grade, loss of institutional privileges, or academic suspension or dismissal may be imposed.

The Dean of Students Office administers this faculty-approved policy. Within the Dean of Students Office, two administrators will facilitate the separate aspects of the policy, including the initial resolution and appeal process, in order to remain impartial with respect to potential appeals while simultaneously providing procedural guidance to faculty and students.

Forms of Misconduct. As a guide, some of the more common forms of academic misconduct are noted below. This list is not intended to be all-inclusive; rather, the list is illustrative of practices the Mines faculty have deemed inappropriate.

1. **Dishonest Conduct** – general conduct unbecoming a scholar. Examples include issuing misleading statements; withholding pertinent information; submitting previously graded work as new and/or original without acknowledgment and permission; not fulfilling, in a timely fashion, previously agreed to projects or activities; and

verifying as true things that are known to the student not to be true or verifiable.

2. **Plagiarism** – presenting the work of another as one's own. This is usually accomplished through the failure to acknowledge the borrowing of ideas, data, or the words of others. Examples include submitting as one's own work the work of another student, a ghost writer, or a commercial writing service; quoting, either directly or paraphrased, a source without appropriate acknowledgment; and using figures, charts, graphs, or facts without appropriate acknowledgment. Inadvertent or unintentional misuse or appropriation of another's work is nevertheless plagiarism.
3. **Falsification/Fabrication** – inventing or altering information. Examples include inventing or manipulating data or research procedures to report, suggest, or imply that particular results were achieved from procedures when such procedures were not actually undertaken or when such results were not actually supported by the pertinent data; false citation of source materials; reporting false information about practical, laboratory, or clinical experiences; falsifying attendance or participation; submitting false excuses for absence, tardiness, or missed deadlines; and altering previously submitted examinations.
4. **Tampering** – interfering with, forging, altering, or attempting to alter university records, grades, assignments, or other documents without authorization. Examples include using a computer- or false-written document to change a recorded grade; altering, deleting, or manufacturing any academic record; and gaining unauthorized access to a university record by any means.
5. **Cheating** – using or attempting to use unauthorized materials or aid with the intent of demonstrating academic performance through fraudulent means. Examples include copying from another student's paper or receiving unauthorized assistance on a homework assignment, quiz, test, or examination; using books, notes, or other devices such as calculators, PDAs, and cell phones, unless explicitly authorized; acquiring without authorization a copy of the examination before the scheduled examination; and copying reports, laboratory work, or computer files from other students. Authorized materials are those generally regarded as being appropriate in an academic setting, unless specific exceptions have been articulated by the instructor.
6. **Impeding** – negatively impacting the ability of other students to successfully complete course or degree requirements. Examples include removing pages from books and removing materials that are placed on reserve in the library for general use; failing to provide team members necessary materials or assistance; and, knowingly disseminating false information about the nature of a test or examination.
7. **Sharing Work** – giving or attempting to give unauthorized materials or aid to another student. Examples include allowing another student to copy your work; giving unauthorized assistance on a homework assignment, quiz, test, or examination; providing, without authorization, copies of examinations before the scheduled examination; posting work on a website for others to see; and sharing reports, laboratory work or computer files with other students.

Additionally, individual courses may specify appropriate and/or inappropriate scholastic conduct as long as course-specific guidance is not in conflict with this senior university misconduct policy and is well known by way of advanced written distribution to all students enrolled (e.g., published course syllabus). Students are encouraged to seek prior authorization and permission to use online homework or tutoring sites including, but not limited to, CHEGG. The Academic Misconduct Policy prohibits unauthorized help or assistance. Unauthorized use of CHEGG or similar sites to the benefit of studying, homework, or examinations may result in academic misconduct investigations/sanctions. Viewing, uploading, and downloading material is not tolerated when the course material was illegally or improperly uploaded. Contact your faculty member to proactively seek permission or clarity.

Allegations of misconduct brought forward by faculty must fall within with the aforementioned seven examples of common misconduct and/or be specifically and explicitly addressed in the published course materials.

3.0 PROCEDURES FOR ADDRESSING ACADEMIC MISCONDUCT

Faculty members and thesis committees have discretion to address and resolve misconduct matters in a manner that is commensurate with the infraction and consistent with the values of the Institution. This includes imposition of appropriate academic sanctions for students involved in academic misconduct. However, in order to maintain consistency when handling such issues, if a member of the Mines' community has grounds for suspecting that a student or students have engaged in academic misconduct, they have an obligation to act on this suspicion by utilizing the following procedure:

3.1 Notify the Dean of Students Office. Upon suspicion of misconduct, it is the faculty member's responsibility to email the Dean of Students Office (deanofstudents@mines.edu). The Dean of Students Office will provide procedural guidance to the faculty member, including pre-written email templates which the faculty may use.

Student names may be disclosed at this time, but are not necessary. Prepared sample templates and procedural guidance will consider and include appropriate accessibility language to ensure an accessible process for students and faculty, alike.

3.2 Notify and Meet with Student(s). Following correspondence with the Dean of Students Office, the faculty member or thesis committee representative must meet with and inform the student(s) of the suspicions/allegations and potential charge of academic misconduct within 10 business days of suspecting misconduct.

This meeting allows the student the opportunity to give their perspective or explanation prior to any decision being made as to whether or not misconduct occurred. The student should be aware of the subject of the meeting and the alleged misconduct at the time of scheduling. The meeting also allows the faculty member to have a conversation with the student(s) in an effort to educate them on appropriate conduct.

Following this meeting (at end of meeting or afterward and within the prescribed timeline), the faculty member should inform the student of their decision as to whether or not misconduct occurred. In the instance where the faculty member(s) believe misconduct occurred, the student should be explicitly informed of the nature of the misconduct (e.g., cheating, plagiarism, etc.).

The meeting can be done via telephone if needed, but a face-to-face meeting between the faculty member and student is preferred. It is recommended, but not required, that the faculty invite a neutral, silent colleague to the meeting as an impartial witness. If the student or faculty member is unable to meet because of pre-existing commitments or unforeseen priorities, the ten-day timeline may be temporarily suspended with mutual written agreement of faculty and student(s), and written approval by the Dean of Students Office prior to expiration of the deadline.

3.3. Actions Taken; Circumstances. The circumstances of the academic misconduct dictate the process to be followed:

3.3.1 Regular Coursework. In the case of an allegation of academic misconduct associated with **regular coursework** (including exams), if after talking with the student, the faculty member finds the student is responsible for academic misconduct the faculty member should:

- Report the violation via this form (or via deanofstudents@mines.edu) within five business days of meeting with the student (as outlined above – see 3.1). The reporting form will collect necessary information on the student(s), violation(s), and course details. Report of a violation should detail the nature of the misconduct (e.g., cheating, plagiarism, etc.). A submitted form will automatically inform the Dean of Students Office.

- The Dean of Students Office will communicate the resolution in writing to the student, the faculty member(s), appropriate members of Academic Affairs, the Office of Graduate Studies (if applicable), the student's advisor, and any additional appropriate parties including Athletics, course coordinators, or the Registrar's Office. The Dean of Students will keep official records on all students with academic misconduct violations. Disciplinary action/ sanctioning for misconduct with regular coursework:

    - First Offense: Zero credit (or no points) on the assignment/exam/effort. Educational sanctioning as prescribed and facilitated by the Dean of Students Office. Notation of first offense in disciplinary record.
        - Failure to comply with educational sanctioning expectations and timeline will result in immediate acceleration of offense to sanctioning prescribed with second offense (F in course and inability to withdraw). Additionally, the student's disciplinary standing will also be upgraded to second offense.
        - With first offense, faculty may choose to provide a restorative credit assignment or make-up quiz or exam wherein students can work to recover credit penalized as part of misconduct sanctioning.
    - Second Offense: F in the course and inability to withdraw. Notation of second offense in disciplinary record.
    - Third or Greater Offense: F in the course. Suspension from school for one-year minimum (calendar year). "Suspension as a result of Academic Misconduct" permanently noted on university transcript. Return to Mines not guaranteed, and only possible by way of Mines Readmissions Committee.

3.3.2 Activities Not Part of Regular Coursework. In the case of an allegation of academic misconduct associated with **activities not a part of regular coursework** (e.g., an allegation of cheating on a comprehensive examination or academic misconduct in connection with a graduate thesis project), if after talking with the student, faculty member(s) finds the student is responsible for misconduct the faculty should:

- Report the violation using this form (or via deanofstudents@mines.edu) within five business days of meeting with the student (as outlined above – see 3.1). The reporting form will collect information on the student(s), violation(s), and other necessary course information. (e.g. cheating, plagiarism, etc.).The Dean of Students Office will communicate the resolution in writing to the student, the faculty member(s), appropriate members of Academic Affairs, the Office of Graduate Studies (if applicable), the student's advisor, and any additional appropriate parties including Athletics, course coordinators, or the Registrar's Office. The Dean of Students will keep official records on all students with academic misconduct violations.
- Assign an outcome to the activity that constitutes failure. If appropriate, the student's advisor may also assign a grade of PRU (unsatisfactory progress) for research credits in which the student is enrolled. Regular institutional procedures resulting from either of these outcomes are then followed. Faculty members may impose a lesser penalty if the circumstances warrant, however, the typical sanction is failure.

3.3.3 Research Activities. In the case of an allegation of academic misconduct associated with **research activities**, investigation and resolution of the misconduct is governed by the institution's Research Integrity Policy. The Research Integrity Policy is available as section 10.3 of the Faculty Handbook. If, after talking with the student, the faculty member feels the student is responsible for misconduct of this type, the faculty member should proceed as indicted in the Research Integrity Policy. If appropriate, the student's advisor may also assign a grade of PRU for research credits in which the student is enrolled. Regular institutional procedures resulting from this grade assignment are then followed.

3.4 Student Reporting. Students who suspect other students of academic misconduct should report the matter to the appropriate faculty member, the appropriate department head/program director, the Dean of Undergraduate Studies, the Dean of Graduate Studies, or the Dean of Students. The information is then provided to the faculty member concerned.

4.0 STUDENT ACADEMIC MISCONDUCT APPEAL PROCESS

4.1 Purpose

A student may appeal a decision within certain timelines and under specific criteria. For all charges of academic misconduct, upon notification of a finding of academic misconduct and the associated penalties, the student may appeal the decision of the faculty member.

An appeal is not a second hearing of the case, but rather it is a review of the procedures followed and information presented to determine if the process provided was in accordance with the policy or if the decision was unsupported by the evidence, as set forth below.

This appeal process governs all requests for appeal related to violations of the Academic Integrity/Misconduct Policy. Grade appeals, residency appeals, student conduct appeals, and appeals related to research misconduct are handled through separate processes. Please see the Mines Policy webpage for more information on those processes.

4.2 Grounds for Appeal

An appeal request will be considered only if it includes the specific grounds for an appeal and the rationale that support the selected grounds. The three items listed below are the only acceptable grounds for an appeal:

- **Due Process**. To determine whether the meeting with the faculty member and the process followed was conducted fairly and in conformity with the prescribed procedures. Any procedural errors must have been so substantial as to effectively deny the student a reasonable opportunity to prepare and present information about an alleged policy violation. The student should be able to show that there would have been a different outcome if the procedural error had not occurred. Minor deviations that do not materially affect the outcome are not a basis for sustaining an appeal.
- **New Information**. To consider information or other relevant facts sufficient to alter a decision because such information was not known by the student at the time of the original conduct meeting with the faculty member.
- **Unsupported Decision**. To determine whether the decision reached by the faculty member was supported using the preponderance of evidence standard to establish that a violation of the policy occurred. This ground for appeal requires the student to show that no reasonable person could have determined that the student was responsible or could have imposed the sanctioned issued based on the available evidence.

4.3 Submitting an Appeal Request

Decisions reached by a faculty member may be appealed by the student. A student may file an appeal by completing a Student Conduct Appeal form and submitting it to the Dean of Students Office by the date stated on the original decision letter (typically seven business days). This form is available online at https://www.mines.edu/policy-library/student/ and in person at the Student Life Office. It is the student's obligation to complete the form in its entirety and provide any and all materials that they wish to have considered at the time of the appeal submission. Incomplete form, late submissions, or revised requests will not be accepted. If the student's appeal request is not received by the designated deadline, the decision of the faculty member is final and no further appeal will be permitted.

4.3.1 Appeal Request Review. Once an appeal request is received, it is forwarded to the Dean of Students. Within five business days, the Dean of Students will review the request to determine if the acceptable grounds for an appeal have been met, if the appeal has been timely filed, and if the request is complete. After review of the request, the Dean of Students will take one of the following actions:

a. Accept the Appeal Request – See section 4.3.2 below
b. Deny the Appeal Request – The Dean of Students will notify the student that the appeal has been denied and the basis for the denial. An appeal that does not set forth sufficient grounds for appeal (as described in section 2.0 above) will be denied. In such cases, the original decision of the faculty member is considered binding upon all involved and the matter will be considered closed unless the student can provide evidence that the Dean of Students made an arbitrary decision without fully considering the information presented. If that is the case, the student requesting the appeal must notify the associate vice president of Student Life in writing within two business days and request that the appeal be reviewed again by the associate vice president of Student Life. The associate vice president of Student Life will review the request within two business days. The associate vice president of Student Life will either accept the appeal request (see section 3.2) or deny the appeal request. If the associate vice president of Student Life denies the appeal request, the decision is final and considered binding upon all involved.

4.3.2 Accepted Appeal. Once the appeal request has been accepted by the Dean of Students (or associate vice president of Student Life), the Dean of Students will proceed as follows:

a. Notify the student and the faculty member that the appeal has been accepted and the appeal will proceed.
b. Schedule a date and time for the appeal meeting to be held.
c. Provide the student and faculty member with an overview of the appeal process and allow them to submit any additional information related to the academic misconduct charge that they would like to be included in the appeal meeting.
d. Forward the appeal and all supporting documents to the participating members of the Student Conduct Appeals Board.

4.4 Student Conduct Appeals Board

The Student Conduct Appeals Board ("Board") consists of 16 members of the campus community, including six students, six faculty, and four staff, plus the Dean of Students as the chair. A minimum of three Board members (including one student and one faculty member) are required for all appeal meetings.

Upon acceptance of an appeal, the list of the members of the Student Conduct Appeals Board will be provided to the student and the faculty member. Both the student and the faculty member may each request the removal of one of the Board members' from participating in the appeal meeting. Upon receipt of such requests, the Dean of Students will remove the potential member from participating.

Once an appeal request is accepted and the appeal meeting scheduled, non-excluded Board members will be contacted and invited to participate at the appeal meeting. Appeals Board members have an affirmative obligation to excuse themselves if they have a conflict of interest. The Dean of Students will provide participating Board members with all pertinent information regarding the incident and appeal, including but not limited to the student's education records, the appeal request, and other information submitted by the student and the faculty member.

4.5 Appeal Meeting

The student and the faculty member will meet with the participating Student Conduct Appeals Board members during the appeal meeting. Both the student and the faculty member will be allowed to provide a brief statement and then answer questions from the Appeals Board members. The student and faculty member will not be permitted to question one another. All questioning will be done by the Board members. The Board members may, at their discretion, meet with any appropriate witnesses during the meeting. After all questioning has occurred, the student and faculty member will be excused.

4.5.1 Recordings*.* If requested by the student or faculty member, one verbatim record, such as a recording, will be made. This recording shall be the property of Mines. If such a recording is made, a student wishing to obtain a copy of the recording must submit a request to the Dean of Students. This may be done via mail, email, or in person. Once the request has been received, the Dean of Students will provide both parties with a copy of the recording.

4.5.2 Advisor. The appeal meeting is an internal university judicial matter. Students are allowed to have one individual advisor (parent, lawyer, friend etc.) in the room during the appeal meeting. The advisor is not allowed to speak on the student's behalf or address the committee during the appeal meeting. He/she is only allowed to hear the information being provided to the committee, confer with the student, and offer the student advice. This individual is not permitted to represent the student or speak on the student's behalf during the appeal meeting.

4.6 Pending Action

Throughout the entire appeal process, and while the decision of the Dean of Students or the Student Conduct Appeals Committee is pending, the student must continue to comply with all conditions of the original decision made by the faculty member. Unless otherwise specified in the original written notification of suspension, a student may continue to attend classes while the appeal is pending.

4.7 Decision

At the conclusion of the appeal meeting, the Student Conduct Appeals Board will make one of the following decisions:

1. Reverse the decision of the faculty member and withdraw the charge from the student's record.
2. Affirm the decision of the faculty member and uphold the sanction(s).
3. Forward the case to the Office of Academic Affairs for further consideration: the Student Conduct Appeals Board believes that additional matters implicated in the appeal should be reviewed and considered which could include increasing or decreasing the sanctions imposed or addressing additional issues that arose through the appeal process. Recommendations for appropriate sanctions should be made by the Student Appeals Committee to the Office of Academic Affairs. The additional review and consideration will be conducted by the Dean of Undergraduate Studies or Dean of Graduate Studies, depending on the academic standing of the student requesting the appeal. The Office of Academic Affairs staff member will make a final decision that will be communicated to the student within 10 business days.

The decision made will be communicated to the student and faculty member within 24 hours of the conclusion of the appeal meeting. The decision issued by the Student Conduct Appeals Board or the Office of Academic Affairs (in matters that are forwarded for further consideration) is final and shall be considered binding upon all involved, to which no additional appeals are permitted.

For the most up-to-date version of this procedure and appeal request forms, please see the student section of the policy website*.*

POLICY PROHIBITING UNLAWFUL DISCRIMINATION

1.0. BACKGROUND AND PURPOSE

Colorado School of Mines ("Mines") is committed to inclusivity and access for all persons and strives to create learning and workplace environments that exclude all forms of unlawful discrimination, harassment, and retaliation. Mines' commitment to nondiscrimination, affirmative action, equal opportunity, and equal access is reflected in the administration of its policies, procedures, programs, and activities, as well as its efforts to achieve a diverse student body and workforce.

As part of this commitment, the Board of Trustees of Colorado School of Mines promulgates this policy pursuant to the authority conferred by §23-41-104(1), C.R.S., and in accordance with applicable federal and Colorado civil rights laws.

2.0 POLICY STATEMENT

Mines prohibits discrimination and harassment on the basis of age, ancestry, creed, marital status, race, color, ethnicity, religion, national origin, sex, gender, gender identity, gender expression, disability, sexual orientation, genetic information, veteran status, or military service. This prohibition applies to all students, employees, contractors, visitors, and volunteers.

Mines will not tolerate retaliation against Mines community members for filing complaints regarding or implicating any of these protected statuses, or otherwise participating in investigations regarding such complaints.

It is a violation of this policy to intentionally submit a false complaint or file a complaint that is not made in good faith or to provide materially false or misleading information during an investigation.

3.0 RESPONSIBILITIES

The Board of Trustees directs the president, or the president's delegates to develop, manage, and maintain appropriate procedures and resources to implement this policy.

4.0 COMPLIANCE/ENFORCEMENT

Violators of this policy will be subject to disciplinary action, up to and including termination of employment, expulsion, and termination of contractual relationships with Mines.

5.0 EXCLUSIONS/DISCLAIMER

No one filing a complaint under this policy will be permitted to simultaneously file a grievance under the State of Colorado Personnel Board Rules or Colorado School of Mines Faculty Handbook against the same individual and arising out of the same event(s).

6.0 RESOURCES OR ATTACHMENTS

- Equal Pay Act of 1963
- Titles IV, VI, and VII of the Civil Rights Act of 1964
- Title IX of the Education Amendments of 1972
- Rehabilitation Act of 1973 (sections 503 and 504)
- Vietnam Era Veterans Readjustment Assistance Act
- Age Discrimination Act
- Pregnancy Discrimination Act
- Age Discrimination in Employment Act of 1976
- Americans with Disabilities Act (as amended)
- Executive Order 11246
- Jeanne Clery Disclosure of Campus Security Policy and Crime Statistics Act of 1991
- Uniform Services Employment and Reemployment Act
- Violence Against Women Act of 1994
- Violence Against Women Reauthorization Act of 2013
- Colorado Anti-Discrimination Act
- Statement of Equal Opportunity, Access, and Nondiscrimination (https://www.mines.edu/equal-opportunity/)
- Title IX Office website: https://www.mines.edu/title-ix/
- Human Resources website: https://www.mines.edu/human-resources/

KEY WORDS
Discrimination, harassment, age, ancestry, creed, marital status, race, color, ethnicity, religion, national origin, sex, gender, gender identity, gender expression, disability, sexual orientation, genetic information, veteran status, military service

HISTORY & REVIEW CYCLE

***For a complete policy statement** and the most up-to-date procedures, please see the* policy website*. Promulgated by the Mines Board of Trustees on March 13, 1992. Amended by the Mines Board of Trustees on June 10, 1999; June 22, 2000; June 7, 2003; August 14, 2007; August 29, 2014; February 8, 2019; and August 14, 2020.*

Alcohol and Other Drugs Education and Prevention Policy

In compliance with the federal government's Drug Free Schools and Communities Act, there are community standards and potential consequences at Colorado School of Mines pertaining to the illegal use of alcohol or drugs. The unlawful possession, use, or distribution of illicit drugs and the unlawful or unauthorized use of alcohol by employees and students at Mines will result in disciplinary action consistent with School policies, and local, state, and federal laws.

While Colorado's constitution allows for specific legal use, possession, and growing of marijuana under certain circumstances, because of Mines' status as a federal contractor and grant recipient and because marijuana use is still prohibited under federal law, the use, possession, and growing of marijuana on campus is prohibited. Student use of alcohol and other drugs (including marijuana) that results in an impaired ability to perform academically, or behavior that violates the Code of Conduct constitutes a violation of this policy.

For more information, or for further policy details, please see the Alcohol and Other Drugs Education and Prevention Policy and the Colorado Drug Law Summary in the Policy Library, student section. Also see the Residence Life Policies and the Annual Campus Security and Fire Safety Report for more on programming and requirements.

Electronic Communications (Email) Policy

1.0 BACKGROUND AND PURPOSE

Communication to students at Colorado School of Mines (Mines) is an important element of the official business of the university. It is vital that Mines have an efficient and workable means of getting important and timely information to students. Examples of communications that require timely distribution include information from Fiscal Services, the Registrar's Office, or other offices on campus that need to deliver official and time-sensitive information to students. (Please note that emergency communications may occur in various forms based on the specific circumstances).

Electronic communication through email and Trailhead Portal announcements provides a rapid, efficient, and effective form of communication. Reliance on electronic communication has become the accepted norm within the Mines community. Additionally, utilizing electronic communications is consistent with encouraging a more environmentally conscious means of doing business and encouraging continued stewardship of scarce resources. Because of the widespread use and acceptance of electronic communication, Mines is adopting the following policy regarding electronic communications with students.

2.0 POLICY

It is the policy of Colorado School of Mines that official university-related communications with students will be sent via Mines' internal email system or via campus or targeted Trailhead announcements. All students will be assigned a Mines email address and are expected to periodically check their Mines assigned email as well as their Trailhead portal page. It is also expected that email sent to students will be read in a timely manner. Communications sent via email to students will be considered to have been received and read by the intended recipients.

For a complete policy statement and associated procedures please see the policy website, information technology section. ***The policy website shall be considered the official & controlling Mines' policy.*** Nothing in the procedures should be construed as prohibiting university-related communications being sent via traditional means. Use of paper-based communication may be necessary under certain circumstances or may be more appropriate to certain circumstances. Examples of such communications could include, but not be limited to disciplinary notices, fiscal services communications, graduation information, and so forth.

Questions about this policy may be directed to either of the following: Registrar's Office at 303-273-3200 or registrar@mines.edu; or

Computing, Communications & Information Technologies (CCIT) at 303-273-3431 or complete a request form at the Mines Help Center.

Student Complaint Process

Students are consumers of services offered as part of their academic and co-curricular experience at Colorado School of Mines. If a student needs to make a complaint, specific or general, about their experience at Mines, he or she should contact the Office of the Dean of Students at 303-273-3288. If the issue is related to discrimination, sexual harassment, or sexual violence, there are specific procedures that will be followed (these are noted and linked in this section, or contact the Director, Title IX & Equity, 303-273-2558. Additional contacts listed in the Title IX section below.) For all other concerns, the student should begin with the Dean's Office if interested in making any complaint. All complaints, as well as the interests of all involved parties, will be considered with fairness, impartiality, and promptness while a complaint is being researched and/or investigated by the school.

Access to Student Records

The Family Educational Rights and Privacy Act (FERPA) gives students who reach the age of 18 or who attend a postsecondary institution the right to inspect, review, and request amendment their own Education Records. At the postsecondary level, parents have no inherent rights to inspect, review, or request amendment to a student's Education Records. Mines will provide an annual notice of rights under FERPA to students currently attending the University. Mines may disclose information contained in a student's Education Record as set forth in the Mines Notice of Student Rights Under the Family Educational Rights and Privacy Act of 1974. Mines will securely destroy Education Records that are no longer required to be maintained using a method that renders the content irretrievable and illegible.

Contact information for FERPA complaints:

Family Policy Compliance Office
U.S. Department of Education
400 Maryland Avenue, SW
Washington, D. C. 20202-4605

Directory Information. The school maintains lists of information which may be considered directory information as defined by the regulations. This information includes name, current and permanent addresses and phone numbers, date of birth, major field of study, dates of attendance, part- or full-time status, degrees awarded, last school attended, participation in officially recognized activities and sports, class, academic honors, university email address, and photo including student ID picture. Students who desire that this information not be printed or released must so inform the registrar before the end of the first two weeks of the fall semester for which the student is registered. Information will be withheld for the entire academic year unless the student changes this request. The student's signature is required to make any changes for the current academic year. The request must be renewed each fall term for the upcoming year. The following student records are maintained by Colorado School of Mines at the various offices listed below:

1. General Records: Registrar and Graduate Dean
2. Transcript of Grades: Registrar
3. Computer Grade Lists: Registrar
4. Encumbrance List: Controller and Registrar
5. Academic Probation/Suspension List: Dean of Students and Graduate Dean
6. Advisor File: Academic Advisor
7. Option/Advisor/Enrolled/ Minority/Foreign List: Registrar, Dean of Students, and Graduate Dean
8. Externally Generated SAT/GRE Score Lists: Graduate Dean
9. Financial Aid File: Financial Aid (closed records)
10. Medical History File: School Physician (closed records)

Access to Records by Other Parties. Colorado School of Mines will not permit access to student records by persons outside the school except as follows:

1. In the case of open record information as specified in the section under Directory Information.
2. To those people specifically designated by the student. Examples would include request for transcript to be sent to graduate school or prospective employer.
3. Information required by a state or federal agency for the purpose of establishing eligibility for financial aid.
4. Accreditation agencies during their on-campus review.
5. In compliance with a judicial order or lawfully issued subpoena after the student has been notified of the intended compliance.
6. Any institutional information for statistical purposes which is not identifiable with a particular student.
7. In compliance with any applicable statue now in effect or later enacted. Each individual record (general, transcript, advisor, and medical) will include a log of those persons not employed by Colorado School of Mines who have requested or obtained access to the student record and the legitimate interest that the person has in making the request.

The school discloses education records without a student's prior written consent under the FERPA exception for disclosure to school officials with legitimate educational interests. A school official is a person employed by the school in an administrative, supervisory, academic or research, or support staff position (including law enforcement unit personnel and health staff); a person or company with whom the school has contracted as its agent to provide a service instead of using school employees or officials (such as an attorney, auditor, or collection agent); a person serving on the Board of Trustees; or a student serving on an official committee, such as a disciplinary or grievance committee, or assisting another school official in performing his or her tasks.

A school official has a legitimate educational interest if the official needs to review an education record in order to fulfill his or her professional responsibilities for the school.

See also https://www.mines.edu/policy-library/ferpa-policy/.

Posthumous Degree Awards

The faculty may recognize the accomplishments of students who have died while pursuing their educational goals. If it is reasonable to expect that the student would have completed his or her degree requirements, the faculty may award a baccalaureate or graduate degree that is in all ways identical to the degree the student was pursuing. Alternatively, the faculty may award a posthumous BS, MS, or PhD to commemorate students who distinguished themselves while at Mines by bringing honor to the school and its traditions.

Consideration for either of these degrees begins with a petition to the Faculty Senate from an academic department or degree granting unit. The petition should identify the degree sought. In the event that the degree-granting unit is seeking a conventional degree award, the petition should include evidence of the reasonable expectations that the student would have completed his or her degree requirements. For a baccalaureate, such evidence could consist of, but is not limited to:

- The student was a senior in the final semester of coursework,
- The student was enrolled in courses that would have completed the degree requirements at the time of death
- The student would have passed the courses with an acceptable grade, and would likely have fulfilled the requirements of the degree.

For a Graduate Degree:

- For graduate degrees not requiring a research product, the student was enrolled in courses that would have completed the degree requirements at the time of death, would have passed the courses with an acceptable grade, and would likely have fulfilled the requirements of the degree.
- For graduate degrees requiring a research product, the student had completed all course and mastery requirements pursuant to the degree and was near completion of the dissertation or thesis, and the student's committee found the work to be substantial and worthy of the degree.

The requirement that there be a reasonable expectation of degree completion should be interpreted liberally and weight should be given to the judgment of the departmental representative(s) supporting the petition.

In the event that the degree being sought is a posthumous BS, MS, or PhD, the petition should include evidence that the student conducted himself or herself in the best tradition of a Mines' graduate and is therefore deserving of that honor.

Equal Opportunity, Equal Access, and Affirmative Action

The institution's Statement of Equal Opportunity and Equal Access to Educational Programs and associated staff contacts can be found in the Welcome Section of this Catalog as well as on the policy webpage. Colorado School of Mines maintains an affirmative action plan, which is available at the Arthur Lakes Library, the Dean of Students Office, and the Office of Human Resources.

Office of Institutional Equity and Title IX

Pursuant to Title IX of the Education Amendments of 1972, 20 U.S.C. § 1681, and 34 CFR Part 106, Mines does not discriminate on the basis of sex in any of its education programs or activities, including admissions and employment. All inquiries about the application of Title IX or Part 106 may be directed to Mines Title IX Coordinator or the Assistant Secretary of Education, U.S. Department of Education, or both:

Mines Title IX Coordinator is Carole Goddard.
Office: Title IX House, 1706 Illinois Street
Email: titleix@mines.edu
Phone: 303-273-3260
Website: https://www.mines.edu/institutional-equity-title-ix/

The Policy Prohibiting Sexual Harassment, Sexual Assault, and Interpersonal Violence can be found here: https://www.mines.edu/policy-library/policy-prohibiting-sexual-misconduct-discrimination-and-retaliation/

The Procedure to Resolve Complaints of Sexual Harassment, Sexual Assault, and Interpersonal Violence can be found here: https://www.mines.edu/policy-library/procedure-a-resolution-for-complaints-of-sexual-misconduct-under-title-ix/.

Additionally, student complaints of discrimination, harassment, and retaliation on the basis of a protected class (race, color, religion or creed, sex [including pregnancy, childbirth, related medical conditions, sexual orientation, gender identity, and gender expression], marital status, ethnicity, national origin, age, disability, genetic information, ancestry, and veteran status or military service), are managed through the Office of Equity and Title IX. The Policy Prohibiting Unlawful Discrimination is listed above and can also be found here: https://www.mines.edu/policy-library/procedure-b-resolution-for-complaints-of-sexual-misconduct-discrimination-and-retaliation/.

SpeakUP@Mines

Students and employees have an additional anonymous channel for reporting concerns through the Whistleblower Policy and the SpeakUP@Mines program.

Consumer Information – Your Right to Know

As a prospective or continuing student at Colorado School of Mines, you have a right to certain information that the university is required by law to provide. Much of that information is safety related or financial in nature, but other broad categories are included such as graduation rates, athletics, and the various costs associated with attending Mines.

Current federal regulations require that institutions of higher education disclose such information and make it readily available to current and prospective students. A new provision in the Higher Education Amendments of 1998 requires institutions to provide a list of the information to which students are entitled with instructions on how they may obtain it. A paper copy of all the information can be found in the Compliance and Policy Office in Guggenheim Hall.

More information can be found on the Financial Aid website.

Directory of the School

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Index