Table of Contents

Colorado School of Mines Catalog

Mission, Vision and Values

Colorado statues define the role of the Colorado School of Mines as: *The Colorado School of Mines shall be a specialized baccalaureate and graduate research institution with high admission standards. The Colorado School of Mines shall have a unique mission in energy, mineral, and materials science and engineering and associated engineering and science fields. The school shall be the primary institution of higher education offering energy, mineral and materials science and mineral engineering degrees at both the graduate and undergraduate levels. (Colorado revised Statutes: Section 23-41-105).*

The Board of Trustees of the Colorado School of Mines has elaborated on this statutory role with the following statement of the School's mission, vision and values.

Mission

Education and research in engineering and science to solve the world's challenges related to the earth, energy and the environment

- Colorado School of Mines educates students and creates knowledge to address the needs and aspirations of the world's growing population.
- Mines embraces engineering, the sciences, and associated fields related to the discovery and recovery of the Earth's resources, the conversion of resources to materials and energy, development of advanced processes and products, fundamental knowledge and technologies that support the physical and biological sciences, and the economic, social and environmental systems necessary for a sustainable global society.
- Mines empowers, and holds accountable, its faculty, students, and staff to achieve excellence in its academic programs, its research, and in its application of knowledge for the development of technology.

Vision

Mines will be the premier institution, based on the impact of its graduates and research programs, in engineering and science relating to the earth, energy and the environment

- Colorado School of Mines is a world-renowned institution that continually enhances its leadership in educational and research programs that serve constituencies throughout Colorado, the nation, and the world.
- Mines is widely acclaimed as an educational institution focused on stewardship of the earth, development of materials, overcoming the earth's energy challenges, and fostering environmentally sound and sustainable solutions.

Values

A student-centered institution focused on education that promotes collaboration, integrity, perseverance, creativity, life-long learning, and a responsibility for developing a better world

- The Mines student graduates with a strong sense of integrity, intellectual curiosity, demonstrated ability to get a job done in collaborative environments, passion to achieve goals, and an enhanced sense of responsibility to promote positive change in the world.
- Mines is committed to providing a quality experience for students, faculty, and staff through student programs, excellence in pedagogy and research, and an engaged and supportive campus community.
- Mines actively promotes ethical and responsible behaviors as a part of all aspects of campus life.

(Colorado School of Mines Board of Trustees, 2013)

Graduate

To Mines Graduate Students:
This Catalog is for your use as a source of continuing reference. Please save it.

Published by:
Colorado School of Mines,
Golden, CO 80401

Address correspondence to:

Office of Graduate Studies
Colorado School of Mines
Student Center Suite E140
1200 16th St
Golden, CO 80401-1887
Main Telephone: 303-273-3247
Toll Free: 800-446-9488
https://www.mines.edu/graduate-studies/contact/

Academic Calendar

Fall Semester 2018

Description	Date(s)	Day(s) of Week
Confirmation Deadline	Aug. 17	Friday
Faculty Conference	Aug. 17	Friday
Classes Start (1)	Aug. 20	Monday
Graduate Student Registration Deadline - Late Fee Applied After this Date	Aug. 24	Friday
Labor Day - Campus Closed	Sep. 3	Monday
Census Day	Sep. 5	Wednesday
Fall Break (not always Columbus Day)	Oct. 15 & 16	Monday & Tuesday
Midterm Grades Due	Oct. 15	Monday
Last Withdrawal - Continuing Students (12 wks)	Nov. 9	Friday
Priority Registration for Spring Term	Nov. 12-16	Monday - Friday
Non-Class Day prior to Thanksgiving Break	Nov. 21	Wednesday
Thanksgiving Break - Campus Closed	Nov. 22-23	Thursday & Friday
Last Withdrawal - New Freshmen & Transfers	Nov. 30	Friday
Classes End	Dec. 6	Thursday
Dead Week - no exams	Dec. 3-7	Monday - Friday
Dead Day - no academic activities	Dec. 7	Friday
Final Exams	Dec. 8, 10-13	Saturday, Monday - Thursday
Commencement	Dec. 14	Friday
Semester Ends	Dec. 14	Friday
Final Grades Due	Dec. 17	Monday
Winter Break	Dec. 17 - Jan 7	

Spring Semester 2019

Description	Date(s)	Day(s) of Week
Confirmation Deadline	Jan. 7	Monday
Classes Start (1)	Jan. 8	Tuesday
Graduate Student Registration Deadline - Late Fee Applied After this Date	Jan. 11	Friday
Martin Luther King Day - Campus Closed	Jan. 21	Monday
Census Day	Jan. 23	Wednesday
Non-Class Day - President's Day (2 days)	Feb. 18-19	Monday-Tuesday
Midterm Grades Due	Mar. 4	Monday
Spring Break	Mar. 23 - Mar. 31	Saturday - Sunday
Priority Registration Summer I & II, Fall	April 1 - 5	Monday - Friday
Last Withdrawal - Continuing & Grad (13 weeks)	April 10	Wednesday
E-Days	April 12-14	Friday - Sunday
Last Withdrawal - New Freshmen, New Transfers, New Graduate Students in the first two semesters at CSM	April 26	Friday
Classes End	May 2	Thursday
Dead Week - No Exams	Apr. 29 - May 3	Monday - Friday
Dead Day - No Academic Activities	May 3	Friday
Final Exams	May 4, 6-9	Saturday, Monday - Thursday
Commencement - Grad	May 10	Friday
Commencement - UG	May 10	Friday
Semester Ends	May 10	Friday
Final Grades Due	May 13	Monday

Summer Sessions 2019

Description	Date(s)	Day(s) of Week
Summer I Starts (6-week session) (1)	May 13	Monday
Summer I Census	May 17	Friday
Memorial Day - No Classes, Campus Closed	May 27	Monday
Summer I Last Withdrawal - All Students	June 7	Friday
Summer I Ends	June 21	Friday
Summer I Grades Due	June 24	Monday
Summer II Starts (6-week session) (1)	June 24	Monday
Summer II Census	June 28	Friday
Independence Day - No Classes, Campus Closed	July 4	Thursday
Summer II Last Withdrawal - All Students	July 19	Friday
Summer II Ends (2)	Aug. 2	Friday
Summer II Grades Due	Aug. 5	Monday
Summer II Last Withdrawal (8-week physics courses only)	Aug. 2	Friday
Summer II Ends (8-week physics courses only)	Aug. 15	Thursday
Summer II Grades Due (8-week physics curses only)	Aug. 19	Monday
Summer Grades Available on Transcript	Aug. 21	Wednesday

1. Petitions for changes in tuition classification due in the Registrar's Office for this term.
2. PHGN courses end two weeks later on Thursday, August 16th.

General Information

Institutional Values and Principles

Graduate Education

The Colorado School of Mines is dedicated to serving the people of Colorado, the nation and the global community by providing high quality educational and research experiences to students in science, engineering and related areas that support the institutional mission. Recognizing the importance of responsible earth stewardship, Mines places particular emphasis on those fields related to the discovery, production and utilization of resources needed to improve the quality of life of the world's inhabitants and to sustain the earth system upon which all life and development depend. To this end, Mines is devoted to creating a learning community that provides students with perspectives informed by the humanities and social sciences, perspectives that also enhance students' understanding of themselves and their role in contemporary society. Mines therefore seeks to instill in all graduate students a broad class of developmental and educational attributes that are guided by a set of institutionally vetted educational objectives and student learning outcomes. For doctoral and master's degree programs, these are summarized below.

Doctoral Programs

Institutional Educational Objectives:

1. PhD graduates will advance the state of the art of their discipline (integrating existing knowledge and creating new knowledge) by conducting independent research that addresses relevant disciplinary issues and by disseminating their research results to appropriate target audiences.
2. PhD graduates will be scholars and international leaders who exhibit the highest standards of integrity.
3. PhD graduates will advance in their professions and assume leadership positions in industry, government and academia.

Institutional Student Outcomes:

1. Demonstration of exemplary disciplinary expertise.
2. Demonstration of a set of skills and attitudes usually associated with our understanding of what it is to be an academic scholar (e.g., intellectual curiosity, intellectual integrity, ability to think critically and argue persuasively, the exercise of intellectual independence, a passion for life-long learning, etc.).
3. Demonstration of a set of professional skills (e.g., oral and written communication, time-management, project planning, teaching, teamwork and team leadership, cross-cultural and diversity awareness, etc.) necessary to succeed in a student's chosen career path.

Master's Programs

The Colorado School of Mines offers a wide variety of Master's-level degree programs that include thesis and non-thesis Master of Science programs, Master of Engineering programs and Professional Master's programs. While the objectives and outcomes provided below document expectations of all Master's-level programs, it is expected that given the diversity of program types, different programs will emphasize some objectives and outcomes more than others.

Institutional Educational Objectives:

1. Master's graduates will contribute to the advancement of their chosen fields through adopting, applying and evaluating state-of-the-art practices.
2. Master's graduates will be viewed within their organizations as technologically advanced and abreast of the latest scholarship.
3. Master's graduates will exhibit the highest standards of integrity in applying scholarship.
4. Master's graduates will advance in their professions.

Institutional Student Outcomes:

1. Graduates will demonstrate exemplary disciplinary expertise.
2. Graduates will demonstrate the ability to conduct direct research; the ability to assimilate and assess scholarship; and the ability to apply scholarship in new, creative and productive ways.
3. Graduates will demonstrate professional skills (e.g., oral and written communication, time-management, project planning, teamwork and team leadership, cross-cultural and diversity awareness, ethics, etc.) necessary to succeed in a student's chosen career path.

Research

The creation and dissemination of new knowledge are primary responsibilities of all members of the university community and fundamental to the educational and societal missions of the institution. Public institutions have an additional responsibility to use that knowledge to contribute to the economic growth and public welfare of the society from which they receive their charter and support. As a public institution of higher education, a fundamental responsibility of Mines is to provide an environment that enables contribution to the public good by encouraging creative research and ensuring the free exchange of ideas, information, and results. To this end, the institution acknowledges the following responsibilities:

- To insure that these activities are conducted in an environment of minimum influence and bias, it is essential that Mines protect the academic freedom of all members of its community.
- To provide the mechanisms for creation and dissemination of knowledge, the institution recognizes that access to information and information technology (e.g. library, computing and internet resources) are part of the basic infrastructure support to which every member of the community is entitled.
- To promote the utilization and application of knowledge, it is incumbent upon Mines to define and protect the intellectual-property rights and responsibilities of faculty members, students, as well as the institution.
- To insure integration of research activities into its basic educational mission, its research policies and practices conform to the state non-competition law requiring all research projects have an educational component through the involvement of students and/or post-doctoral fellows.

Intellectual Property

The creation and dissemination of knowledge are primary responsibilities of all members of the university community. As an institution of higher education, a fundamental mission of Mines is to provide an environment that motivates the faculty and promotes the creation, dissemination, and application of knowledge through the timely and free exchange of ideas, information, and research results for the public good. To insure that these activities are conducted in an environment of minimum influence and bias, so as to benefit society and the people of Colorado, it is essential that Mines protect the academic freedom of all members of its community. It is incumbent upon Mines to help promote the utilization and application of knowledge by defining and protecting the rights and responsibilities of faculty members, students and the institution, with respect to intellectual property which may be created while an individual is employed as a faculty member or enrolled as a student.

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.

Location

Golden, Colorado, has always been the home of Mines. Located in the foothills of the Rocky Mountains 20 minutes west of Denver, this community of 15,000 also serves as home to the Coors Brewing Company, the National Renewable Energy Laboratory, and a major U.S. Geological Survey facility that also contains the National Earthquake Center. The seat of government for Jefferson County, Golden once served as the territorial capital of Colorado. Skiing is an hour away to the west.

Administration

By State statute, the school is managed by a seven-member board of trustees appointed by the governor, and the student and faculty bodies elect one nonvoting board member each The school is supported financially by student tuition and fees and by the State through annual appropriations. These funds are augmented by government and privately sponsored research, and 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:

EO and Discrimination contact is:
Karin Ranta-Curran, Associate Vice President for Organizational Strategy
Guggenheim Hall, Room 110
Golden, Colorado 80401
(Telephone: 303.384.2558)
(email: krcurran@mines.edu)

The ADA Coordinator and the Section 504 Coordinator for employment is:
Karin Ranta-Curran, Associate Vice President for Organizational Strategy
Guggenheim Hall, Room 110
Golden, Colorado 80401
(Telephone: 303.384.2558)
(email: krcurran@mines.edu)

The ADA Coordinator and the Section 504 Coordinator for students and academic educational programs is:
Katie Ludwin, Director of Disability Support Services
Student Wellness Center, 1770 Elm Street
Golden, Colorado 80401
(Telephone: 303.273.3377)

The Title IX Coordinator is:
Karin Ranta-Curran, Associate Vice President for Organizational Strategy
Guggenheim Hall, Room 110
Golden, Colorado 80401
(Telephone: 303.384.2558)
(email: krcurran@mines.edu)

The ADA Facilities Access Coordinator is:
Gary Bowersock, Director of Facilities Management
1318 Maple Street
Golden, Colorado 80401
(Telephone: 303.273.3330)

The Graduate School

2018-2019

https://www.mines.edu/graduate-studies/

Unique Programs

Because of its special focus, Colorado School of Mines has unique programs in many fields. For example, Mines is the only institution in the world 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 also 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 the traditional programs defining the institutional focus, Mines is pioneering both undergraduate and graduate interdisciplinary programs. The School understands that solutions to the complex problems involving global processes and quality of life issues require cooperation among scientists, engineers, economists, and the humanities.

Mines offers interdisciplinary programs in areas such as materials science, hydrology, nuclear engineering and geochemistry. These programs make interdisciplinary connections between traditional fields of engineering, physical science and social science, emphasizing a broad exposure to fundamental principles while cross-linking information from traditional disciplines to create the insight needed for breakthroughs in the solution of modern problems. Additional interdisciplinary degree programs may be created by Mines' faculty as need arises and offered with the degree title "Interdisciplinary". Currently, one additional interdisciplinary degree is offered through this program. It is a specialty offering in operations research with engineering.

Lastly, Mines offers a variety of non-thesis Professional Master's degrees to meet the career needs of working professionals in Mines' focus areas.

Graduate Degrees Offered

Mines offers professional master's, master of science (M.S.), master of engineering (M.E.) and doctor of philosophy (Ph.D.) degrees in the disciplines listed in the chart.

In addition to master's and Ph.D. degrees, departments and divisions can also offer graduate certificates. Graduate certificates are designed to have selective focus, short time to completion, and consist of course work only.

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

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

The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology accredits undergraduate degree programs in chemical engineering, engineering, engineering physics, geological engineering, geophysical engineering, metallurgical and materials engineering, mining engineering and petroleum engineering. The American Chemical Society has approved the degree program in the Department of Chemistry and Geochemistry.

Degree Programs	Prof.	M.S.	M.E.	Ph.D.	Cert.
Advanced Manufacturing		x			x
Applied Mathematics and Statistics		x		x	
Applied Physics		x		x	
Chemical & Biological Engineering		x		x	
Chemistry		x			
Applied Chemistry				x	
Civil & Environmental Engineering		x		x	
Computer Sciences		x		x	
Data Center					x
Electrical Engineering		x		x	
Engineering & Technology Management		x			
Environmental Geochemistry	x				
Environmental Engineering & Science		x		x	
Geochemistry		x		x	
Geological Engineering		x	x	x	
Geology		x		x	
Geophysical Engineering		x		x	
Geophysics		x		x	
Hydrology		x		x	
Materials Science		x		x	
Mechanical Engineering		x		x	
Metallurgical & Materials Engineering		x	x	x	
Mineral & Energy Economics		x		x	
Mineral Exploration	x				
Mining & Earth Systems Engineering		x	x	x	
Mining Engineering and Management	x				
Natural Resources and Energy Policy		x			x
Nuclear Engineering		x	x	x	
Operations Research with Engineering*				x	
Petroleum Engineering		x	x	x	
Petroleum Reservoir Systems	x				
Quantitative Biosciences and Engineering		x		x	
Space Resources		x		x	x
Underground Construction and Tunnel Engineering		x		x	

* Interdisciplinary degree with specialty in Operations Research with Engineering

Admission to the Graduate School

Admission Requirements

The Graduate School of Colorado School of Mines is open to graduates from recognized colleges and universities worldwide. Admission to all graduate programs is competitive, based on an evaluation of prior academic performance, test scores and references. The academic background of each applicant is evaluated according to the requirements of each program outlined later in this section of the Catalog.

To be a candidate for a graduate degree, students must have completed an appropriate undergraduate degree program. Colorado School of Mines undergraduate students in the Combined Degree Program may, however, work toward completion of graduate degree requirements prior to completing undergraduate degree requirements. See the Combined Undergraduate/Graduate Degree section of the Graduate Catalog for details of this program.

Categories of Admission

There are four categories of admission to graduate studies at Colorado School of Mines: regular, provisional, graduate non-degree, and foreign exchange.

Regular Degree Students

Applicants who meet all the necessary qualifications as determined by the program to which they have applied are admitted as regular graduate students.

Provisional Degree Students

Applicants who are not qualified to enter the regular degree program directly may be admitted as provisional degree students for a trial period not longer than 12 months. During this period students must demonstrate their ability to work for an advanced degree as specified by the admitting degree program. After the first semester, the student may request that the department review his or her progress and make a decision concerning full degree status. With department approval, the credits earned under the provisional status can be applied towards the advanced degree.

Non-degree Students

Practicing professionals may wish to update their professional knowledge or broaden their areas of competence without committing themselves to a degree program. They may enroll for regular courses as non-degree students. Inquiries and applications should be made to:

Office of Graduate Studies
Ben Parker Student Center, E140
grad-app@mines.edu
Phone: 303-273-3247

A person admitted as a non-degree student who subsequently decides to pursue a regular degree program must apply and gain admission to the Graduate School.

- All graduate-level credits earned as a non-degree graduate student may be used towards the regular graduate degree program if the credits are not prerequisites or deficiencies and the student's graduate committee and department head approve. Graduate non-degree credits count towards the student’s graduate cumulative G.P.A. and could impact student’s academic standing as a degree seeking graduate student.
- Graduate credits earned as a non-degree undergraduate student may be transferred into the regular graduate degree program if the credits are 400 level or higher (graduate students are limited to 9 credits of 400 level coursework), the credits do not exceed the transfer limits, the transfer credits must not have been used as credit toward a Bachelor's degree (students will be required to obtain proof from the bachelor’s degree institution), the transfer credits are not prerequisites or deficiency credits and the student’s graduate committee and department head approve. Graduate credits taken while an undergraduate non-degree seeking student count towards the students undergraduate G.P.A.

Foreign Exchange Students

Graduate level students living outside of the U.S. may wish to take courses at Colorado School of Mines as exchange students. They may enroll for regular courses as foreign exchange students. Inquiries and applications should be made to:

Mines Office of International Programs
Golden, CO 80401-0028
Phone: 303-384-2121

A person admitted as a foreign exchange student who subsequently decides to pursue a regular degree program must apply and gain admission to the Graduate School.

- All graduate-level credits earned as a graduate foreign exchange student may be used towards the regular graduate degree if the credits are not prerequisites or deficiencies and the student’s graduate committee and department head approve. Graduate exchange credits count towards the student’s cumulative GPA and could impact academic standing as a degree seeking student.
- Graduate credits earned as an exchange undergraduate student may be transferred into the regular graduate degree program if the credits are 400 level or higher (graduate students are limited to 9 credits of 400 level coursework), the credits do not exceed the transfer limits, the transfer credits were not used toward a bachelor's degree (students will be required to obtain proof from the bachelor degree institution), transfer credits are not prerequisites or deficiency credits and the student's graduate committee and department head approve.

Combined Undergraduate/Graduate Programs

Several degree programs offer Mines undergraduate students the opportunity to begin work on a Graduate Degree while completing the requirements of their Bachelor 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 (http://bulletin.mines.edu/graduate/programs) section of this Catalog.

Admission into a Combined Undergraduate/Graduate degree program is available only to current Mines undergraduate students. Mines alumni are not eligible for Combined degree program enrollment.

Combined students whose graduate degree programs allow double counting of credits, may only double count if the student has uninterrupted registration from the undergraduate degree to the graduate degree. If a student takes a semester off between degrees (summer excluded), the combined student is no longer eligible to double count credits.

Admission Procedure

Applying for Admission

Both US resident and international students may apply electronically for admission. The graduate admissions web address is: https://www.mines.edu/graduate-admissions/

To apply follow the procedure outlined below.

1. Application: Go to the online application form at https://www.mines.edu/graduate-admissions/apply. Students wishing to apply for graduate school should submit completed applications by the following dates:
   for Fall admission*
   December 15 - Priority consideration for financial support
   March 1 - International student deadline
   July 1 - Domestic student deadline
   for Spring Admission*
   October 1
   * Some programs have different application deadlines. Please refer to https://www.mines.edu/graduate-admissions/deadlines/ for current deadline information for specific programs. Students wishing to submit applications beyond the final deadline should contact the academic program.

2. Transcripts: The Office of Graduate Studies recommends uploading electronic copies of transcripts (in .pdf format) within the online application system from each school previously attended. Electronic copies of transcripts can also be sent, via email, to grad.credentials@mines.edu. International students' transcripts must be in English or have an official English translation attached. Transcripts are not considered official unless they are sent directly by the institution attended and are complete, with no courses in progress.
3. Letters of Recommendation: Three (3) letters of recommendation are required. Individuals who know your personal qualities and scholastic or professional abilities can use the online application system to submit letters of recommendation on your behalf. Letters can also be mailed directly to the Office of Graduate Studies.
4. Graduate Record Examination (GRE): Most departments require the General test of the Graduate Record Examination for applicants seeking admission to their programs. Refer to the section Graduate Degree Programs and Courses by Department or the Graduate School application packet to find out if you must take the GRE examination. For information about the test, write to:
   Graduate Record Examinations
   Educational Testing Service
   PO Box 6000
   Princeton, NJ 08541- 6000
   (Telephone 609-771-7670)
   or visit online at www.gre.org (http://www.gre.org)
5. English Language Requirements: Applicants whose native language is not English must prove proficiency. Language examination results must be sent to the Graduate School as part of the admission process. The institution has minimum English proficiency requirements - learn more at: https://www.mines.edu/graduate-admissions/international-applicants/.
   English proficiency may be proven by achieving one of the following:
   a. A TOEFL (Test of English as a Foreign Language) minimum score of 79 on the internet Based TOEFL (iBT).
   b. An IELTS (International English Language Testing System) Score of 6.5, with no band below a 6.0.
   c. A PTE A (Pearson test of English) score of 70 or higher.
   d. Independent evaluation and approval by the admission-granting department.

6. Additional instructions for admission to graduate school specific to individual departments are contained in the application for admission.

RESEARCH OR TEACHING ASSISTANTSHIP

To be considered for a Research or Teaching Assistantship select 'Yes' for that question under the Educational Information section of the online graduate application.

Application Review Process

After all application materials are received by the Office of Graduate Studies the application is complete and is released to the desired degree program for review. The review is conducted according to the process developed and approved by the faculty of that degree program. The degree program transmits its decision back to the Office of Graduate Studies, which then notifies the applicant. The decision of the degree program is final and may not be appealed.

Health Record and Additional Steps

When students first enroll at Mines, they must complete the student health record form which is sent to them when they are accepted for enrollment. Students must submit the student health record, including health history, medical examination, and record of immunization, in order to complete registration.

Questions can be addressed to:
The Coulter Student Health Center
1225 17th Street
Golden, CO 80401-1869

The Health Center telephone numbers are 303-273-3381 and 303-279-3155.

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 credit hours, and graduate students must register for and maintain 9.0 credit hours 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 3/4 time, 1/2 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 credit hours to meet the physical education undergraduate degree requirement at Mines. Additionally, veterans may request substitution of a technical elective for the institution's core EPICS course requirement in all undergraduate degree programs.

For more information, please visit the Veterans Services (http://inside.mines.edu/Veterans-Services) webpage.

Student Life at CSM

Housing (https://www.mines.edu/residence-life/mines-park)

Graduate students may choose to reside in campus-owned apartment housing areas on a space-available basis. The Mines Park apartment complex is located west of the 6th Avenue and 19th Street intersection on 55 acres owned by Mines. The complex houses upperclass undergraduate students, graduate students, and families. Residents must be full-time students.

Units are complete with refrigerators, stoves, dishwashers, streaming television services, and wired/wireless internet connections. There are two community centers which contain the laundry facilities, recreational and study space, and meeting rooms. For more information or to apply for apartment housing, go to the Apartment Housing website (https://www.mines.edu/residence-life/mines-park).

For all Housing & Dining rates, go to Room and Board Rates (https://www.mines.edu/residence-life/rates).

Facilities

Student Center

The Ben H. Parker Student Center contains the offices for the Vice President of Student Life, Student Activities, Involvement and Leadership, Undergraduate Student Government (USG), Financial Aid, Bursar and Cashier, International Office, Career Center, Graduate Studies, Registrar, Campus Events, 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 Intramurals 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 Student Health Insurance Plan , the Counseling Center, the Dental Clinic and Disability Support Services. The Wellness Center is open from 8:00 am to 5:00 pm, Monday through Friday during the fall and spring semesters. Check the website for summer and holiday hours. The Wellness Center follows the delay and closure schedule set for the campus.

Coulter Student Health Center: Services are provided to all students who have paid the student health services fee. 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 at the corner of 18th and Elm Streets (1770 Elm Street). Nurse practitioners and registered nurses provide services by appointment Monday through Friday 8:00 am to 12:00 pm and 1:00 pm to 4:45 pm. Family medicine physicians provide services by appointment several days a week. After hours students can call New West Physicians at (303) 278-4600 to speak to the physician on call (identify yourself as a Mines student). The Health Center offers primary health care. 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: *The State of Colorado requires that all students enrolled have proof of two MMR vaccines (Measles, Mumps and Rubella). A blood test showing immunity to all three diseases is acceptable. History of disease is not acceptable. Proof of a Meningococcal vaccine given within the past five years is required of all students living in campus housing. Exemptions to these requirements may be honored with proper documentation. Completion of the Tuberculosis questionnaire is required - TB testing may be required.*

Dental Clinic: The Dental Clinic is located on the second floor of the W. Lloyd Wright Wellness Center. Services include cleanings, restoratives, and x-rays. Students who have paid the student health services fee are eligible for this service. The dental clinic is open Tuesdays, Wednesdays, and Fridays during the academic year with fewer hours in the summer. Services are by appointment only and can be made by calling the Dental Clinic, phone 303-273-3377. Dental care is on a fee-for-service basis. The Dental Clinic accepts cash or checks, as well as credit/debit cards.

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

Student Health Insurance Plan: *The SHIP office is located on the second floor of the W. Lloyd Wright Student Wellness Center.*

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 http://studentinsurance.mines.edu or by calling 303.273.3388. Enrollment confirmation or waiver of the Mines Student Health Insurance Plan is done online. The deadline to submit a waiver is Census Day.*

Counseling Center: *Located on the second floor of the W. Lloyd Wright Student Wellness Center, phone 303-273-3377. Individual mental health counseling is offered on a short-term basis to enrolled Mines students who have paid the student services fee. In cases where a student requires long term or specialized counseling, referrals are made to local providers. The Counseling Center also provides workshops, groups and online tools and resources. More information is available at https://www.mines.edu/counseling-center/.*

Disability Support Services*: Located on the second floor of the W. Lloyd Wright Student Wellness Center, phone 303-273-3377. Student Disability Services provides students with disabilities and equal opportunity to access the institution's courses, programs and activities. Services are available to students with a variety of disabilities, including but not limited to attention deficit hyperactivity disorders, learning disorders, psychological disorders, vision impairment, hearing impairment, and other disabilities. A student requesting disability accommodations at the Colorado School of Mines must comply with the Documentation Guidelines and submit required documents, along with a completed Request for Reasonable Accommodations form to Student Disability Services.*

Documentation Guidelines and the Request form are available at https://www.mines.edu/disability-support-services/.

Services

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 Mines 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/

Career Center

The Mines Career Center mission is to assist students in developing, evaluating, and/or implementing career, education, and employment decisions and plans. Career 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 organization in a variety of forums to enhance their professional knowledge and diversity of career prospects.

Services are provided to all students and for all 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 in its entirety on the Student's Homepage of DiggerNet. In order to accomplish our mission, we provide a comprehensive array of career services:

Career, Planning, Advice, and Counseling

- "The Mines Strategy" a practical, user-friendly 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 video-taped interviews;
- Job Search Workshops - successful company research, interviewing, resumes, professional branding, networking skills;
- Career resource library.

Job Resources and Events

- Career Day (Fall and Spring);
- Online job search system: DiggerNet;
- Job search assistance for on-campus jobs (work-study / student worker);
- Online and in-person job search assistance for internships, CO-OPs, and full-time entry-level job postings;
- On-Campus Student Worker Job Fair (Fall and Spring);
- Virtual Career Fairs and special recruiting events;
- On-campus interviewing - industry and government representatives visit the campus to interview students and explain employment opportunities;
- General employment board;
- Company research resource;
- Cooperative Education Program.

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. Students can replace lost, stolen, or damaged Blaster Cards for a small fee.

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.

Standards, Codes of Conduct

Students can access campus rules and regulations, including the student code of conduct, student honor code, alcohol policy, sexual misconduct policy, the unlawful discrimination policy and complaint procedure, public safety and parking policies, and the distribution of literature and free speech policy, by visiting the Policy Library website at https://www.mines.edu/policy-library/. We encourage all students to review the electronic document 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 Student's Office located in the Campus Living Office, room 271.

Student Publications

Two student publications are published at Mines by the Associated Students of CSM. Opportunities abound for students wishing to participate on the staffs. A Board of Student Publications 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 veterans services for students attending the School and using educational benefits from the Veterans Administration.

Activities

Office of Student Activities, Involvement and Leadership (https://www.mines.edu/student-activities)

The Office of 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 Mines 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 Graduate Student Government was formed in 1991 and is recognized by Mines as the representative voice of the graduate student body. GSG’s primary goal is to improve the quality of graduate education and offer academic support for graduate students.

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 Mines 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

Engineers' Days festivities are held each spring. The three day affair is organized entirely by students. Contests are held in drilling, hand-spiking, mucking, and oil-field 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 an Engineers' Day 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 Council. 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.

Winter Carnival, sponsored by Blue Key, is an all-school ski day held each year at one of the nearby ski areas. In addition to skiing, there are also fun competitions (snowman contest, sled races, etc.) throughout the day.

Outdoor Recreation Program

The Outdoor Recreation Program is housed at the Mines Park Community 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 hall floor. Officers are elected each fall for that academic year. For more information, go to RHA (https://www.mines.edu/residence-life/residence-hall-association).

Student Organizations

Social Fraternities and Sororities - There are seven national fraternities and three national sororities active on the Mines 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 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 Mines honor societies recognizes different achievements in our students.

Special Interest Groups - Special interest organizations meet the special and unique needs of the Mines 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.

For a complete list of all currently registered student organizations, please visit the SAIL office or website at https://www.mines.edu/student-activities/.

Registration and Tuition Classification

General Registration Requirements

The normal full-time credit load for graduate students is 9 credit hours per term.

Full-time graduate students may register for an overload of up to 6 credit hours (up to 15 credit hours total) per term at no increase in tuition. Subject to written approval by their advisor and department head or division director, students may register for more than 15 credit hours per term by paying additional tuition at the regular part-time rate for all hours over 15. The maximum number of credits for which a student can register during the summer is 12.

Students in any of the following categories must register as full-time students.

- International students subject to immigration requirements. This applies to international students holding J-1 and F-1 visas.
- Students receiving financial assistance in the form of graduate teaching assistantships, research assistantships, fellowships or hourly contracts.
- Students enrolled in academic programs that require full-time registration. Refer to the degree program sections of this catalog to see if this applies to a particular program.

Special cases to the full-time registration requirement for students listed above are under Full Time Status-Required Course load and include first-year international students who must receive special instruction to improve their language skills, and thesis based students who have completed their credit-hour requirements, have completed all required paperwork, are eligible for reduced registration and are working full time on their thesis (see section on reduced registration). To remain active in their degree program, all graduate students must register continuously each fall and spring semester. If not required to register full-time, students may register as a part-time student for any number of credit hours (1.0 credit hour minimum) Students who wish to take a semester off must submit the Leave of Absence paperwork, or the degree will be terminated.

Summer registration is not required to maintain an active program. Students who continue to work on their degree program and utilize Mines facilities during the summer, however, must register. Students registered during the summer are assessed regular tuition and fees.

New graduate students are expected to register for and pay for credits for the admittance term, including summer admittance.

Graduate students who register for credits in any term are responsible for payment for those credits. Payment information can be found here: https://www.mines.edu/controllers-office/accounts-receivable-and-cashiering/.

Graduate students who wish to be dropped from all credits in a term must either submit the Leave of Absence paperwork or the Withdrawal from Graduate School paperwork by Census Day of that term. Students who submit either form after census may be withdrawn from credits, but will still owe the portion of tuition and fees due at the time of withdrawal.

It is the student's responsibility to submit either the Leave of Absence form or the Withdrawal from Graduate School form. Students who wish to be dropped or withdraw from all credits, but do not submit either the Leave of Absence form or the Withdrawal form will be responsible for paying all the tuition and fees.

Research Registration

In addition to completing prescribed course work and defending a thesis, students in thesis-based degree programs must complete a research experience under the direct supervision of their faculty advisor or co-advisor. Master students must complete a minimum of 6* hours of research credit, and doctoral students must complete a minimum of 24* hours of research credit at Mines. While completing this experience, students register for research credit under course numbers 707. Faculty assign grades indicating satisfactory or unsatisfactory progress based on their evaluation of the student's work. Students registered for research during the summer semester and working on campus must pay regular tuition and thesis research fees for summer semester. Students may not transfer research credits from other institutions, so students working on research abroad must either register for research credits at Mines or submit the Leave of Absence paperwork. Those who take the leave of absence may not use any Mines campus resources, including, but not limited to consultations with advisors, committee members and other Mines students during the term of leave.

* Departmental requirements may require students to complete more than the institutional minimum number of research credits.

Eligibility for Reduced Registration

Students enrolled in thesis-based degree programs who have completed a minimum number of course and research credit hours in their degree programs are eligible to continue to pursue their graduate program as full-time students at a reduced registration level. In order to be considered for this reduced, full-time registration category, students must satisfy the following requirements:

1. For M.S. students,
    a. Completion of 36 hours of eligible course, research, and transfer credits combined, and
    b. Paid for 27 credits.
        i 1-9 credits per semester count as paid credits; 10-15 credits do not count as paid credits.
2. For PhD students,
    a. Completion of 72 hours of eligible course, research, and transfer credits combined, and
    b. Paid for 54 credits.
        i 1-9 credits per semester count as paid credits; 10-15 credits do not count as paid credits.
3. For all students, an approved Committee form and Degree Audit form must be on file in the Graduate Office the semester prior to one for which you are applying for reduced registration*.
4. PhD students must submit an approved Admission to Candidacy form by the first day of class in which the student would like reduced registration*.

* See OGS Graduation Deadlines website for specific deadlines (https://www.mines.edu/graduate-studies/graduation-deadlines). Students who are eligible for reduced registration are considered full time if they register for 4 credit hours of research under course number 707.

Full-time Status - Required Course Load

To be deemed full-time during the fall and spring semesters, students must register for at least 9 credit hours. In the event a thesis-based student has completed his or her required course work and research credits, has completed all required forms, and has received confirmation from the Office of Graduate Studies that (s)he is eligible for reduced registration, the student will be deemed full-time if he or she is registered for at least 4 credit hours of research credit.

To be deemed full-time during the summer semester, students must register for a minimum of 3 credit hours.

Late Registration Fee

Students must complete their registration by the date specified in the Academic Calendar. Students who fail to complete their registration during this time will be assessed a $100 late registration fee and will not receive any tuition fellowships for which they might otherwise be eligible.

Reciprocal Registration

Under the Reciprocal Exchange Agreement Between the State Supported Institutions in Northern Colorado, Mines graduate students who are paying full-time tuition may take courses at Colorado State University, University of Northern Colorado, and University of Colorado (Boulder, Denver, Colorado Springs, and the Health Sciences Center) at no charge by completing the request form and meeting the required conditions on registration and tuition, course load, and course and space availability. Request forms are available from the Registrar's office and requests for reciprocal course credits are subject to approval by participating schools.

Courses completed under the reciprocal agreement may be applied to a student's degree program, with departmental approval. These are, however, applied as transfer credit into the degree program. In doing so, they are subject to all the limitations, approvals and requirements of any regularly transferred course.

Transfer Credits

With prior approval, graduate students may use transfer coursework credits towards a graduate level degree. All transfer credits must be listed on the Degree Audit form and have the appropriate signatures of approval.

- Master's non-thesis and professional master's students must receive approval from the advisor, co-advisor (if applicable), minor representative (if applicable) and department head.
- Master's thesis and PhD students must receive approval from the advisor, co-advisor (if applicable), all committee members, minor representative (if applicable) and the department head.

Transfer credit limitations apply to all major and minor degrees. Transfer credits may be from a Mines undergraduate transcript or from another university.

- Transfer credits from a Mines undergraduate transcript must be 400 level or higher (graduate students are limited to no more than 9 credits of 400 level coursework), may not have been used towards an undergraduate degree, cannot be for prerequisites or deficiency credits and must have a grade of C or better.
- Transfer credits from other universities must be for course work (research credits cannot be transferred), graduate level with a grade of "C " or better, cannot have been used towards an undergraduate degree and cannot be for prerequisite or deficiency credits. Credits without a letter grade (Pass/Fail, Satisfactory/Unsatisfactory, etc.) will not be accepted as transfer credit.

Grades for transfer credits, either from a Mines undergraduate transcript or from another university will not be transferred and therefore will not impact the students graduate G.P.A.

The Office of Graduate Studies must have official transcripts on file prior to transferring credit from another university. The exception is transfer credits taken under the Reciprocal Agreement, in which case the Registrar's Office must receive the grade from the transfer institution prior to transferring the credit.

Due to time constraints of receiving transcripts and grades, students taking transfer credits in their last semester may not be able to graduate in that semester. Students studying abroad are encouraged to not study abroad during their last semester.

Major degree transfer credit limitations

- 30 credit Master's non-thesis degree programs are limited to no more than 9 transfer credits.
- 36 credit Master's non-thesis degree programs are limited to no more than 15 transfer credits.
- 30-38 credit Master's thesis degree programs are limited to no more than 9 transfer credits.
- PhDs transferring a thesis based master's degree from another university* may transfer no more than 36 credits.
- PhDs transferring individual coursework, or any graduate level degree other than a thesis based master's degree from another university* may transfer no more than 24 credits.
  - *Any credit taken at Mines and listed on a Mines graduate level transcript are not transfer credits.
  - *PhDs may, with committee and department head approval, use all credits from a Mines Master's degree towards a PhD, as long as the credits were not used towards two (2) Mines Master's degrees.

Minor degree transfer credit limitations

- Less than half of the minor credit requirement may be transfer credits.
  - Master's students may transfer no more than 4.0 credits towards a minor
  - PhD students may transfer no more than 5.5 credits towards a minor.

Transfer credit conversion

Colorado School of Mines uses semester credits. Any transfer credits taken at a university that does not use semester credits will have the credits converted. U.S. Quarter credit hours are equivalent to 2/3 semester credit hours. European Credit Transfer and Accumulation

System (ECTS) credits are equivalent to ½ semester credit hours. Other credits will be assessed on an individual basis.

Dropping and Adding Courses

Students may add or drop some, but not all credits through web registration without paying a fee during the first 11 school days of a regular semester, the first four school days of a six-week field course, or the first six school days of an eight-week summer term. Graduate students who wish to drop all credits during the fall or spring term must submit either the Leave of Absence or Withdrawal from Graduate School paperwork to the Office of Graduate Studies by census day.

After the 11th day of classes through the 12th week, continuing students may withdraw from any credits for any reason with a grade of “W”. Graduate students in their first or second semesters at Mines have through the 14th week of that semester to withdraw from credits. A student must process a drop-add form and pay a $5.00 fee for any change in class schedule after the first 11 days of class, except in cases of withdrawal from school. Forms are available in the Registrar’s Office. Graduate students wishing to withdraw from all credits must either submit a Leave of Absence form (https://www.mines.edu/graduate-studies/forms/leave-of-absence) or a Withdrawal from Graduate School form (https://www.mines.edu/graduate-studies/forms/withdraw-from-graduate-school). Those forms are available on the Graduate School website.

After the 12th (or 14th) week, no withdrawals are permitted, except in case of withdrawal from school or for extenuating circumstances. To request consideration of extenuating circumstances, a student must submit a written request to the Graduate Dean, which includes the following:

1. A list of the courses from which they wish to withdraw. This must include all courses for which they are registered.
2. Documentation of the problem which is the basis for the request.
3. If the problem involves a medical condition, the documentation must be signed by a licensed medical doctor or a representative of the Mines Counseling Office.
4. Signatures indicating approval by the student’s advisor and department head or division director.

A student who is allowed to withdraw from courses under this policy will receive a grade of “W” for each course and if the student has not already taken 2 semesters of leave, the student will be placed on automatic leave of absence.

In order to resume the graduate program, any student on leave must submit a Return from Leave form (https://www.mines.edu/graduate-studies/wp-content/uploads/sites/60/2017/11/GS-Return-from-Leave.xls) that includes documentation that the problems which caused the withdrawal have been corrected. The student will be reinstated to active status upon approval by their advisor and their department head or division director.

Students who have already used 2 semesters of leave will need to submit the Withdrawal from Graduate School form. Students who withdraw from graduate school will need to re-apply for admission online and be re-accepted before returning to school.

The financial impact of a withdrawal is covered in the section on “Payments and Refunds.”

Auditing Courses

As part of the maximum of 15 semester hours of graduate work, students may enroll for no credit (NC) in a course with the permission of the instructor. Tuition charges are the same for no credit as for credit enrollment.

Students must enroll for no credit before census day, the last day of registration. The form to enroll for a course for no credit is available in the Registrar’s Office. NC designation is awarded only if all conditions stipulated by course instructors are met.

Mines requires that all U.S. students who are being supported by the institution register full time, and federal financial aid regulations prohibit us from counting NC registration in determining financial aid eligibility. In addition, the INS requires that international students register full time, and we are discouraged from counting NC registration toward that requirement. Furthermore, there are no consistent standards for expectations of students who register for NC in a course. Therefore, in order to treat all Mines students consistently, NC registration will not count toward the minimum number of hours for which students are required to register. This includes the minimum continuous registration requirement of part-time students and the 9 credit-hour requirement for students who must register full time.

The reduced registration policy is based on the principle that the minimum degree requirement (36 or 72 hours) would include only the credits applied toward that degree. Deficiency and extra courses are above and beyond that minimum. NC courses fall into the latter category and may not be applied toward the degree. Therefore, NC registration will not count toward the number of hours required to be eligible for reduced thesis registration.

NC registration may involve additional effort on the part of faculty to give and/or grade assignments or exams, so it is the institution’s policy to charge tuition for NC courses. Therefore, NC registration will count toward the maximum number of credits for which a graduate student may be allowed to register. This includes a tuition surcharge for credits taken over 15.

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 the Office of International Programs at (303) 384-2121; for other information, contact the Registrar’s Office.

Students conducting research off campus must either register for research credits at Mines or submit the Leave of Absence paperwork. Students on leave may not use any campus resources, including work with advisor, committee members and any Mines students.

Students conducting research abroad must comply with the research off-campus rules above and need to register with the Study Abroad Office. Students may not transfer research credits from another university. All graduate students must register for credits at the Colorado School of

Mines for at least one semester. A semester of study abroad does not count towards this requirement.

Students on study abroad who are using study abroad transfer credits towards a degree program must have official transcripts on file with the Office of Graduate Studies prior to graduation. Since foreign transcripts often take longer to arrive than US transcripts, students on study abroad during their last semester, may not be able to graduate in that same semester.

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	Master's Level	
600-699	Doctoral Level	
Over 700	Graduate Research or Thesis Level	

Course Change Crosswalk

Previous Course	Current Course	Meets H&SS Requirement?
EPIC151	EDNS151	
EPIC155	EDNS155	
New Course	EDNS156	
New Course	EDNS157	
EPIC198	EDNS198	
EPIC251	EDNS251	
EPIC261	EDNS261	
EPIC262	EDNS262	
EPIC264	EDNS264	
EPIC267	CEEN267	
EPIC269	EDNS269	
EPIC271	EDNS263	
EPIC298	EDNS298	
EPIC299	EDNS299	
New Course	EDNS315	
EPIC398	EDNS398	
EPIC399	EDNS399	
EPIC497	EDNS497	
EPIC498	EDNS498	
EPIC499	EDNS499	
EGGN191	EDNS191	
EGGN192	EDNS192	
EGGN200	EDNS200	
EGGN205	EDNS205	
EGGN250	MEGN250	
EGGN291	EDNS291	
EGGN292	EDNS292	
EGGN301	EDNS301	
EGGN350	MEGN350	
EGGN391	EDNS391	
EGGN392	EDNS392	
EGGN401	EDNS401	
EGGN408	MEGN408	
EGGN450	MEGN450	
EGGN491	EDNS491	
EGGN492	EDNS492	
EGGN589	EENG589	
LAIS100	HASS100	
LAIS198	HASS198	
LAIS199	HASS199	
LAIS200	HASS200	
LAIS201	HASS201	
LAIS220	HASS220	Mid-Level
LAIS221	HASS221	Mid-Level
LAIS226	HASS226	Mid-Level
LAIS286	HASS286	Mid-Level
LAIS298	HASS298	Mid-Level
LAIS299	HASS299	
LAIS300	HASS300	Mid-Level
LAIS301	HASS301	Mid-Level
LAIS305	HASS305	Mid-Level
LAIS307	HASS307	Mid-Level
LAIS309	HASS309	Mid-Level
LAIS315	HASS315	Mid-Level
LAIS320	HASS320	Mid-Level
LAIS323	HASS323	Mid-Level
LAIS324	HASS324	Mid-Level
LAIS325	HASS325	Mid-Level
LAIS326	HASS326	Mid-Level
LAIS327	HASS327	Mid-Level
LAIS328	HASS328	Mid-Level
LAIS330	HASS330	Mid-Level
LAIS337	HASS337	Mid-Level
LAIS339	HASS339	Mid-Level
LAIS341	HASS341	Mid-Level
LAIS344	HASS344	Mid-Level
LAIS365	HASS365	Mid-Level
LAIS370	HASS370	Mid-Level
LAIS375	EDNS375	Mid-Level
LAIS376	HASS376	Mid-Level
LAIS377	EDNS377	Mid-Level
LAIS398	HASS398	Mid-Level
LAIS399	HASS399	
New Course	HASS400	400-Level
LAIS401	HASS401	400-Level
LAIS404	HASS404	400-Level
LAIS406	HASS406	400-Level
LAIS407	HASS407	400-Level
LAIS408	HASS408	400-Level
LAIS409	HASS409	400-Level
LAIS410	HASS410	400-Level
LAIS411	HASS411	400-Level
LAIS412	HASS412	400-Level
LAIS415	HASS415	400-Level
LAIS416	HASS416	400-Level
LAIS418	HASS418	400-Level
LAIS419	HASS419	400-Level
LAIS421	HASS421	400-Level
LAIS423	HASS423	400-Level
LAIS425	HASS425	400-Level
LAIS426	HASS426	400-Level
LAIS429	HASS429	400-Level
LAIS430	EDNS430	400-Level
LAIS431	HASS431	400-Level
LAIS433	HASS433	400-Level
LAIS435	HASS435	400-Level
LAIS437	HASS437	400-Level
LAIS439	HASS439	400-Level
LAIS441	HASS441	400-Level
LAIS442	HASS442	400-Level

LAIS446	HASS446	400-Level
LAIS448	HASS448	400-Level
LAIS450	HASS450	400-Level
LAIS452	HASS452	400-Level
LAIS453	HASS453	400-Level
LAIS456	HASS456	400-Level
New Course	HASS458	400-Level
LAIS460	HASS460	400-Level
LAIS464	HASS464	400-Level
LAIS467	HASS467	400-Level
LAIS475	EDNS475	400-Level
LAIS478	EDNS478	400-Level
LAIS479	EDNS479	
LAIS480	EDNS480	400-Level
New Course	HASS484	400-Level
LAIS485	HASS485	400-Level
LAIS486	HASS486	400-Level
LAIS487	HASS487	400-Level
LAIS488	HASS488	400-Level
LAIS490	HASS490	400-Level
New Course	HASS491	400-Level
New Course	HASS492	400-Level
LAIS498	HASS498	400-Level
LAIS499	HASS499	
LAIS521	HASS521	
LAIS523	HASS523	
LAIS525	HASS525	
LAIS535	HASS535	
LAIS541	HASS541	
LAIS542	HASS542	
LAIS545	HASS545	
LAIS550	HASS550	
LAIS552	HASS552	
LAIS558	HASS558	
LAIS560	HASS560	
LAIS565	HASS565	
LAIS577	EDNS577	
LAIS578	EDNS578	
LAIS586	HASS586	
LAIS587	HASS587	
LAIS588	HASS588	
LAIS590	HASS590	
New Course	HASS591	
New Course	HASS592	
New Course	HASS593	
LAIS598	HASS598	
LAIS599	HASS599	
LAIS601	HASS601	
LAIS698	HASS698	
LAIS699	HASS699	
LAIS707	HASS707	

Courses no longer offered

CSM191

CSM192

EGGN198

EGGN215

EGGN298

EGGN398

EGGN497

EGGN498

EGGN598

EGGN699

EPIC252

EPIC263

EPIC265

EPIC266

LAIS310

LAIS311

LAIS322

LAIS335

LAIS345

LAIS371

LAIS424

LAIS440

LAIS451

LAIS457

LAIS489

LAIS524

LAIS531

LAIS537

LAIS539

LAIS546

LAIS548

LAIS551

LAIS553

LAIS555

LAIS556

LAIS557

LAIS559

LAIS564

LAIS570

LAIS589

LIFL214

LIFL215

Leave of Absence & Parental Leave

Leave of Absence

Leaves of absence are granted when it is temporarily impossible for students to continue to work toward a degree. Leave of absence requests for the current semester must be received by the Graduate Dean prior to census. Leave forms submitted after census may be considered, but students may only be withdrawn from credits, not dropped. The financial impact of requesting a leave of absence for the current semester is covered in the section on "Payments and Refunds (https://catalog.mines.edu/graduate/tuitionfeesfinancialassistance)". Leave of absence requests for prior semesters will not be considered.

Any request for a leave of absence must have the prior approval of the student's faculty advisor, the Office of International Programs (international students only) and the Graduate Dean. To request a leave of absence, students must submit the Leave of Absence form, along with the following information:

1. the reasons why the student must interrupt his or her studies and,
2. a plan (including a timeline and deadlines) for resuming and completing the work toward the degree in a timely fashion.

Students on leave remain in good standing even though they are not registered for any course or research credits. While on leave, however, students will not have access to Mines resources. This includes, but is not limited to, office space, computational facilities, library, faculty and other Mines students. Students who will be using campus resources in any manner will not be allowed to take a leave and will be required to register for at least one credit.

Students are limited to two, not necessarily consecutive, regular semesters of leave while in a graduate degree program at Mines. Beyond these two semesters, students needing to suspend their degree programs further are required to formally withdraw from the degree program by submitting the Withdrawal from Graduate School paperwork.

Students on a leave of absence must submit the Return from Leave paperwork within the timeframe allowed to continue in the degree program. Students on leave who do not submit the Return from Leave paperwork and do not submit the Withdrawal from Graduate School form will have the degree program terminated, will need to re-apply for admission, be re-admitted and pay a $200 re-admission fee.

Students who withdraw from graduate school need to re-apply, and be readmitted, into the degree program before continuing in the degree program. As with all degree program applications, applications from candidates returning from a leave are reviewed by the program and considered for readmission at the sole discretion of the program.

Students who fail to register and who are not on approved leaves of absence have their degree programs terminated. Students who wish to return to graduate school after an unauthorized leave of absence must apply for readmission and pay a $200 readmission fee.

Parental Leave

Graduate students in thesis-based degree programs, who have full-time student status, may be eligible to request up to eight (8) weeks of parental leave. The Parental Leave Policy is designed to assist students who are primary child-care providers immediately following the birth or adoption of a child. The Policy is designed to make it possible for students to maintain full-time status in research-based degree programs while taking a leave from that program to care for their new child, and facilitate planning for continuance of their degree program.

Nothing in the Parental Leave policy can, or is intended to replace communication and cooperation between the student and his or her advisor, and the good-faith efforts of both to accommodate the birth or adoption of a child within the confines and expectations of participating in a research-active graduate degree program. It is the intent of this Policy to reinforce the importance of this cooperation, and to provide a framework of support and guidance.

Eligibility

In order to be eligible for Parental Leave, a graduate student must:

- be the primary child care provider;
- have been a full-time graduate student in his/her degree program during at least the two (2), prior consecutive semesters;
- be enrolled in a thesis-based degree program (i.e., Doctoral or thesis-based Masters);
- be in good academic standing as defined in the Unsatisfactory Academic Performance section of this Catalog;
- provide a letter from a physician or other health care professional stating the anticipated due date of the child, or provide appropriate documentation specifying an expected date of adoption of the child;
- notify advisor of intent to apply for Parental Leave at least four (4) months prior to the anticipated due date or adoption date; and
- at least two (2) months prior to the expected leave date complete, and have approved, the Request for Parental Leave Form that includes an academic Program Plan for program continuance.

Exceptions and Limitations

This Policy has been explicitly constructed with the following limitations:

- part-time and non-thesis students are not eligible for Parental Leave. These students may, however, apply for a Leave of Absence through the regular procedure defined above;
- if both parents are Mines graduate students who would otherwise qualify for leave under this Policy, each is entitled to a Parental Leave period immediately following the birth or adoption of a child during which he or she is the primary care provider, but the leaves may not be taken simultaneously; and
- leaves extending beyond eight (8) weeks are not covered by this Policy. The regular Leave of Absence policy defined in the Graduate Catalog applies to these cases.

Benefits

Under this Policy students will receive the following benefits and protections:

- a one-semester extension of all academic requirements (e.g., qualifying examinations, time to degree limitations, etc.);
- maintenance of full-time status in degree program while on Parental Leave;
- documentation of an academic plan that specifies both how a student will continue work toward his or her degree prior to the leave period and how a student will reintegrate into a degree program after returning from leave; and

- continuance of assistantship support during the semester in which the leave is taken.

Planning and Approval

It is the student's responsibility to initiate discussions with his/her advisor(s) at least four (4) months prior to the anticipated birth or adoption. This notice provides the lead time necessary to rearrange teaching duties (for those students supported by teaching assistantships), to adjust laboratory and research responsibilities and schedules, to identify and develop plans for addressing any new health and safety issues, and to develop an academic Program Plan that promotes seamless reintegration back into a degree program.

While faculty will make every reasonable effort to meet the needs of students requesting Parental Leave, students must recognize that faculty are ultimately responsible for ensuring the rigor of academic degree programs and may have a direct requirement to meet specific milestones defined in externally funded research contracts. Within this context, faculty may need to reassess and reassign specific work assignments, modify laboratory schedules, etc. Without good communication, such efforts may lead to significant misunderstandings between faculty and students. As such, there must be good-faith, and open communication by each party to meet the needs and expectations of each during this potentially stressful period.

The results of these discussions are to be formalized into an academic Program Plan that is agreed to by both the student and the advisor(s). This Plan, to be accepted, must also receive approval by the appropriate Department Head, Division or Program Director and the Graduate Dean. Approval of the Dean should be sought by submitting to the Office of Graduate Studies a formal Parental Leave request, with all necessary signatures along with the following documentation;

- letter from a physician or other health care professional stating the anticipated due date of the child or other appropriate documentation specifying an expected date of adoption of the child; and
- the advisor(s) and Department Head, Division or Program Director approved academic Program Plan.

These materials should be delivered to the Office of Graduate Studies no less than two (2) months prior to the anticipated date of leave.

If a student and faculty member cannot reach agreement on a Program Plan, they should consult with the appropriate Department Head, Division or Program Director to help mediate and resolve the outstanding issues. As appropriate, the Department Head, Division or Program Director may request the Graduate Dean and the Director of the Women in Science, Engineering and Mathematics (WISEM) program provide additional assistance in finalizing the Program Plan.

Graduate Students with Appointments as Graduate Research and Teaching Assistants

A graduate student who is eligible for Parental Leave and has a continuing appointment as a research or teaching assistant is eligible for continued stipend and tuition support during the semester(s) in which the leave is taken. For consideration of this support, however, the timing of a leave with continued stipend and tuition support must be consistent with the academic unit's prior funding commitment to the student. No financial support will be provided during Leave in a semester in which the student would have otherwise not been funded.

Tuition and Fee Reimbursement: If the assistantship, either teaching or research, would have normally paid a student's tuition and mandatory fees, it will continue to do so for the semester(s) in which the Leave is taken. Costs for tuition will be shared proportionally between the normal source of funding for the research or teaching assistantship and the Office of Graduate Studies.

Stipend Support: Stipends associated with the assistantship will be provided at their full rate for that portion of the semester(s) during which the student is not on Parental Leave. No stipend support need be provided during the time period over which the Parental Leave is taken. The student may, however, choose to have the stipend he or she would receive during the semester(s) in which the Leave is taken delivered in equal increments over the entire semester(s).

While on Leave, students may elect to continue to work in some modified capacity and Faculty, Departments and Programs may elect to provide additional stipend support in recognition of these efforts. Students, however, are under no obligation to do so, and if they choose to not work during their Leave period this will not be held against them when they return from Leave. Upon return, students on Research Assistantships are expected to continue their normal research activities as defined in their Academic Plans. Students on Teaching Assistantships will be directed by the Department, Division or Program as to specific activities in which they will engage upon return from Parental Leave.

Registration

Students on Parental Leave should register at the full-time level for research credit hours under the direction of their Thesis Advisor. The advisor will evaluate student progress toward degree for the semester in which Parental Leave is taken only on those activities undertaken by the student while he or she is not on Leave.

In-State Tuition Classification Status

In-State Tuition Classification Status

General Information

The State of Colorado partially subsidizes the cost of tuition for all students whose domicile, or permanent legal residence, is in Colorado. Each Mines student is classified as either an “in-state resident” or a “non-resident” at the time of matriculation. These classifications, which are governed by Colorado law, are based upon information furnished by each student on his or her application for admission to Mines. A student who willfully furnishes incorrect information to Mines to evade payment of non-resident tuition shall be subject to serious disciplinary action.

It is in the interest of each graduate student who is a U.S. citizen and who is supported on an assistantship or fellowship to become a legal resident of Colorado at the earliest opportunity. Typically, students on an assistantship contract that covers tuition and fees will have the non-resident portion of the tuition paid by Mines during their first year of study only. U.S. citizens are expected to obtain Colorado residency status by the end of the first year of study. After the first year of study, these students who do not obtain residency status may be responsible for paying the difference between resident and non-resident tuition. International students on an assistantship contract that covers tuition and fees will have the non-resident portion of the tuition paid by Mines beyond the 1st year.

Requirements for Establishing In-State Residency

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.

In-state or resident status generally requires domicile in Colorado for the year immediately preceding the beginning of the semester in which in-state status is sought. “Domicile” is “a person’s true, fixed and permanent home and place of habitation.” An unemancipated minor is eligible for in-state status if at least one parent (or his or her court-appointed guardian) has been domiciled in Colorado for at least one year. If neither of the student’s parents are domiciliaries of Colorado, the student must be a qualified person to begin the one-year domiciliary period. A “qualified person” is someone who is at least twenty-two years old, married, or emancipated. A student may prove emancipation if:

1. The student’s parents have entirely surrendered the right to the student’s custody and earnings;
2. The student’s parents are no longer under any duty to financially support the student; and
3. The student’s parents have made no provision for the continuing support of the student.

To begin the one-year domiciliary period, a qualified person must be living in Colorado with the present intention to reside permanently in Colorado. Although none of the following indicia are determinative, voter registration, driver’s license, vehicle registration, state income tax filings, real property interests, and permanent employment (or acceptance of future employment) in Colorado will be considered in determining whether a student has the requisite intention to permanently reside in Colorado. Once a student’s legal residence has been permanently established in Colorado, he or she may continue to be classified as a resident student so long as such residence is maintained, even though circumstances may require extended temporary absences from Colorado.

For more information about the requirements for establishing in-state residency, please contact the Registrar’s Office (http://inside.mines.edu/Petitioning-for-In-State-Tuition-Classification).

Petitioning for In-State Tuition Classification

A continuing, non-resident student who believes that he or she has become eligible for in-state resident tuition due to events that have occurred subsequent to his or her initial enrollment may file a Petition for In-State Tuition Classification with the Registrar’s Office. This petition is due in the Registrar’s Office no later than the first day of the semester for which the student is requesting in-state resident status. Upon receipt of the petition, the Registrar will initially decide whether the student should be granted in-state residency status. The Registrar’s decision may be appealed by petition to the Tuition Classification Review Committee. For more information about this process, please contact the Registrar’s Office (http://inside.mines.edu/Petitioning-for-In-State-Tuition-Classification).

In-State Tuition Classification for WICHE Program Participants

WICHE, the Western Interstate Commission for Higher Education, promotes the sharing of higher education resources among the participating western states. Under this program, residents of Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming who are enrolled in qualifying graduate programs may be eligible for in-state tuition classification. Current qualifying programs include:

- Applied Chemistry
- Environmental Engineering Science
- Geochemistry
- Geological Engineering
- Hydrology
- Mineral and Energy Economics
- Mining and Earth Systems Engineering
- Petroleum Engineering
- Underground Construction & Tunnel Engineering

Contact the Office of Graduate Studies (https://www.mines.edu/graduate-admissions/contact) for more information about WICHE.

Academic Regulations

Graduate School Catalog

It is the responsibility of the graduate 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 current Graduate Catalog when a graduate student first enrolls, gives the academic requirements the student must meet to graduate. However, with department consent, a student can change to the requirements in a later catalog published while the student is enrolled in the graduate school. Changes to administrative policies and procedures become effective for all students as soon as the campus community is notified of the changes.

The Graduate Catalog is available to students in both print and electronic forms. Print catalogs are updated annually. Electronic versions of the Graduate Catalog may be updated more frequently to reflect changes approved by the campus community. As such, students are encouraged to refer to the most recently available electronic version of the Graduate Catalog. This version is available at the CSM website. The electronic version of the Graduate Catalog is considered the official version of this document. In case of disagreement between the electronic and print versions, the electronic version takes precedence.

Resolution of Conflicting Catalog Provisions

If a conflict or inconsistency is found to exist between these policies and any other provision of the Mines Graduate Catalog, the provisions of these policies shall govern the resolution of such conflict or inconsistency.

Curriculum Changes

The Mines Board of Trustees reserves the right to change any course of study or any part of the curriculum to respond to educational and scientific developments. No statement in this Catalog or in the registration of any student shall be considered as a contract between Colorado School of Mines and the student.

Making up Undergraduate Deficiencies

If the department or division decides that new students do not have the necessary background to complete an advanced degree, they will be required to enroll in courses for which they will receive no credit toward their graduate degree, or complete supervised readings, or both. Students are notified of their apparent deficiency areas in their acceptance letter from the Graduate School or in their first interview with their department advisor. Departments will provide the list of deficiencies to the students no later than one week after the start of classes of their first semester in order to allow them to add/drop courses, as necessary. Grades for these deficiency courses are recorded on the student's transcript, become part of the student's permanent record, and are calculated into the overall graduate GPA. Students whose undergraduate records are deficient should remove all deficiencies as soon as possible after they enroll for graduate studies.

Graduate Students in Undergraduate Courses

Students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department-approved 400-level course work not taken to remove deficiencies and not taken as a degree requirement for a bachelor's degree upon the recommendation of the graduate committee and the approval of the Graduate Dean.

Students may apply toward graduate degree requirements 300-level courses only in those programs which have been recommended by the department, are not taken to remove deficiencies, are not taken as a degree requirement for a bachelor's degree and have been approved by the Graduate Council before the student enrolls in the course. In that case a maximum of nine (9.0) total hours of 300- and 400-level courses will be accepted for graduate credit.

Withdrawing from School

To officially withdraw from Mines, a graduate student must submit a Withdrawal from Graduate School form to the Office of Graduate Studies. If the form is submitted by census day, the student will be dropped from all credits and receive a full refund. If the form is submitted after Census Day, the student will receive grades of W in courses in progress and will be charged the amount due at the time of withdrawal (see the Payment and Refund section). If the student does not officially withdraw, the course grades are recorded as F's and the student will be responsible for the tuition and fees due. Leaving school without having paid tuition and fees will result in the encumbrance of the transcript. Federal aid recipients should check with the financial aid office to determine what impact a withdrawal may have on current or future aid.

Students who leave school without submitting a Withdrawal from Graduate School form, but decide to return at a later date, will need to apply for admission, be re-admitted, and will be charged a $200 re-admittance fee.

Independent Studies

To register for independent study course, a student must get the appropriate form from the Registrar's Office (http://inside.mines.edu/Independent-Study-Registration), have it completed by the instructor involved and appropriate department/division head, and return it to the Registrar's Office. The form must be submitted no later than the Census Day (last day of registration) for the term in which the independent study is to be completed.

For each semester credit hour awarded for independent study (x99 course), a student is expected to invest approximately 25.0 contact hours plus 30.0 hours of independent work. Additionally, the faculty certifies that an appropriate course syllabus has been developed for the course, reviewed by the Department/Division and the student, and is available upon request from the department.

Credit Hours	Instructor Contact Hours	Independent Work Hours	Total Hours	Hours Per Week
1.0	25.0	30.0	55.0	3.7
2.0	50.0	60.0	110.0	7.3
3.0	75.0	90.0	165.0	11.0
4.0	100.0	120.0	220.0	14.7
5.0	125.0	150.0	275.0	18.3
6.0	150.0	180.0	330.0	22.0

Non-Degree Students

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 register for courses through the Registrar's Office after degree-seeking students have registered. Such students may take any course for which they have the prerequisites as listed in the Mines Catalog or have the permission of the instructor. Transcripts or evidence of the prerequisites are required. Non-degree students pay all applicable tuition and student fees. Non-degree students are not eligible for financial aid.

Courses completed while the student is a non-degree graduate student count toward the overall graduate-level grade point average on the Mines transcript.

For more information, please visit the Non-Degree Graduate website (https://www.mines.edu/graduate-admissions/non-degree).

Graduate Grading System

Grades

When a student registers in a graduate (500- and 600-level) course, one of the following grades will appear on the academic record. Grades are based on the level of performance and represent the extent of the student's demonstrated mastery of the material listed in the course outline and achievement of the stated course objectives. These are CSM's grade symbols and their qualitative interpretations:

Symbol	Interpretation
A	Acceptable for Graduate Credit
A-	Acceptable for Graduate Credit
B+	Acceptable for Graduate Credit
B	Acceptable for Graduate Credit
B-	May be Acceptable for Graduate Credit
C+	May be Acceptable for Graduate Credit
C	May be Acceptable for Graduate Credit
C-	May be Acceptable for Graduate Credit
D+	Not Acceptable for Graduate Credit
D	Not Acceptable for Graduate Credit
D-	Not Acceptable for Graduate Credit
F	Failed
S	Satisfactory (C- or better, used as a mid-term grade)
U	Unsatisfactory (below C-, used as a mid-term grade)
INC	Incomplete
PRG	Satisfactory Progress
PRU	Unsatisfactory Progress

Graduate students enrolled in undergraduate-level courses (400-level and below) are graded using the undergraduate grading system, but any undergraduate course taken while a graduate student will appear on the graduate level transcript and will impact the graduate level G.P.A.. See the Mines Undergraduate Catalog (https://catalog.mines.edu/undergraduate) for a description of this system.

Any undergraduate taking graduate level credit must complete the 500 level form and agree to the specific terms selected.

- Students requesting the credit for undergraduate credit or those who do not qualify to have the credits listed on the graduate transcripts will have the credit listed on the undergraduate transcripts and the credit will impact the undergraduate G.P.A.
- Students who request the credit for graduate credit only and meet the qualifications to have the credits listed on the graduate level transcript will have the credits listed on the graduate level transcripts and the credits will impact the graduate level G.P.A.

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

Symbol	Interpretation
WI	Involuntarily Withdrawn
W	Withdrew, No Penalty
T	Transfer Credit
NC	Not for Credit
Z	Grade not yet Submitted

Incomplete Grade

If a graduate student fails to complete a course because of illness or other reasonable excuse, the student receives a grade of Incomplete (INC), a temporary grade which indicates a deficiency in the quantity of work done.

A grade of INC must be removed no later than the end of the fourth week of the first major term of attendance following that in which it was received. A grade of INC will be converted to an F grade by the Registrar in the fifth week if it has not been updated by the professor by the end of the fourth week.

Graduating students must have all incomplete grades changed within 10 business days after graduation.

Satisfactory Progress Grades

A graduate student may receive a grade of Satisfactory Progress, PRG, in either one of three possible situations:

1. As a passing grade given in a course that is graded pass-fail,
2. As a grade for a course extending more than one semester or
3. As a grade indicating completion of research credit hours.

When applied to pass-fail courses, the Satisfactory Progress grade, PRG, indicates successful completion of the requirements of the course. A grade of Unsatisfactory Progress, PRU, as applied to pass-fail courses, indicates the student failed to meet the requirements for successful completion the course. The PRG and PRU grades have no point value toward a student's GPA. As described in the Unsatisfactory Academic Performance (https://catalog.mines.edu/graduate/generalregulations/academicperformance) portion of this Catalog receipt of a PRU grade indicates unsatisfactory progress toward degree completion and will trigger academic disciplinary proceedings.

For students completing independent study or seminar courses extending over multiple semesters, the progress grade has no point value. In such cases, the student receives a grade of PRG, which indicates that the work is not yet completed. For multi-semester independent study courses, upon completion of course requirements, final grades are assigned to all semesters in which the student enrolled in the course, replacing previous PRG grades as appropriate. In seminar courses which may not be repeated for credit, even if continuous enrollment is required by the degree program, the PRG grade remains with a final grade being assigned to last semester of attendance only.

For all multi-semester courses, independent study and seminar, students must register for the same course in each regular (Fall or Spring) semester of attendance until such time as a final grade is assigned.

When applied to research credits, the Satisfactory Progress grade, PRG, also has no point value toward a student's GPA, but indicates satisfactory progress toward completion of the research component of a student's thesis-based degree program. In this situation, a grade of PRU, Unsatisfactory Progress, may be given, and if given, indicates that a student has not made satisfactory progress toward the research component of a thesis-based degree program. In this case, receipt of a grade of PRU may trigger academic disciplinary proceedings as described in the Unsatisfactory Academic Performance (https://

catalog.mines.edu/graduate/generalregulations/academicperformance) portion of this Catalog.

Unless faculty submit change of grade forms to the Registrar, grades of PRU delivered for unsatisfactory research performance, are not changed to PRG upon the successful completion of a student's degree program.

NC Grade

For special reasons and with the instructor's permission, a student may register in a course for no credit (NC). To have the grade NC appear on the transcript, the student must enroll at registration time as a NC student in the course and comply with all conditions stipulated by the course instructor. If a student registered as NC fails to satisfy all conditions, no record of this registration in the course will be made.

Quality Hours and Quality Points

For graduation a student must successfully complete a certain number of required semester hours and must maintain grades at a satisfactory level. Numerical values assigned to each letter grade are given in the table below:

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 semester hours assigned to that course multiplied by the numerical value of the grade received. The quality hours earned are the number of semester hours in which grades are awarded. To compute a grade-point average, the number of cumulative quality hours is divided into the cumulative quality points earned. Grades of W, WI, INC, PRG, PRU, or NC are not counted in quality hours.

Semester Hours

The number of times a class meets during a week (for lecture, recitation, or laboratory) determines the number of semester hours 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.

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.

All graduate degree programs require students have a minimum overall grade point average of 3.000 in order to be eligible to receive the degree. All courses, including courses taken as a non-degree graduate student, undergraduate courses taken while a graduate student, deficiency courses and graduate level courses taken at the Colorado School of Mines after first enrolling in a graduate degree program are included in the calculation of the overall graduate grade point average. Grades for courses applied to a degree program as transfer credit are not included in any grade point average calculation. Specifics in calculating the overall, and other grade point averages are defined below.

Overall Grade-Point Average

The overall graduate level grade-point average includes all attempts at courses taken at Colorado School of Mines while a graduate student, either degree seeking or non-degree graduate student, with the exception of courses completed when the repeat policy was in effect: Fall 2007 through Summer 2011.

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 credit hours 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.

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. 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.

All occurrences of every course taken at Colorado School of Mines will appear on the official transcript along with the associated grade. Courses from other institutions transferred to Colorado School of Mines are not counted in any grade-point average.

Course and Research Grades

All candidates for graduate degrees must maintain a cumulative grade point average of at least 3.0 in all courses taken at Mines and listed on the graduate transcript. This includes both graduate and undergraduate courses. Any grade lower than “C-” is not acceptable for credit toward graduate degree requirements.

For research credits, students receive either an “In Progress-Satisfactory” or an “In Progress-Unsatisfactory” grade based on their faculty advisor’s evaluation of their work. Research grades do not enter into the calculation of the student’s grade point average.

Students who fail to maintain a grade point average of at least 3.0, or who receive an In Progress-Unsatisfactory research grade are placed on academic probation by the Graduate Dean and may be subject to dismissal as defined by the Unsatisfactory Academic Performance (https://catalog.mines.edu/graduate/generalregulations/academicperformance) section of this Catalog.

GRADE CHANGES

After completion of final grading for a term, grade changes can be processed for grade improvements only. Grade changes for any student can be accepted up to six weeks after a student's graduation date. 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 the grade to the Faculty Affairs Committee of the Faculty Senate. The Faculty Affairs Committee is the faculty body authorized to review and modify course grades, in appropriate circumstances. Any decision made by the Faculty Affairs Committee is final. In evaluating a grade appeal, the Faculty Affairs Committee will place the burden of proof on the student. For a grade to be revised by the Faculty Affairs 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 or the grade was WI (withdrawn involuntarily).
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 must proceed as follows:

1. The student must prepare a written appeal of the grade received in the course. This appeal must clearly define the basis for the appeal and must present all relevant evidence supporting the student’s case.
2. After preparing the written appeal, the student must 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, the course coordinator (first) or the Department Head/Division Director (second) will represent the instructor.
3. If after discussion with the instructor, the student is still dissatisfied, he or she can proceed with the appeal by submitting three copies of the written appeal plus three copies of a summary of the instructor/student meetings held in connection with the previous step to the President of the Faculty Senate. These must be submitted to the President of the Faculty Senate no later than 25 business days after the start of the regular semester immediately following the semester in which the contested grade was received. The President of the Faculty Senate will forward the student's appeal and supporting documents to the Faculty Affairs Committee, the course instructor's Department Head/Division Director, and the instructor.
4. The Faculty Affairs Committee will request a response to the appeal from the instructor and begin an investigation of the student's allegations and basis for appealing the grade. During the course of performing its investigation, the Committee may:
   a. Interview the student, the student's advisor, the course instructor and other witnesses deemed relevant to the investigation;
   b. Review all documentation related to the appeal under consideration;
   c. Secure the assistance of outside expertise, if needed; and
   d. Obtain any other information deemed necessary to consider and resolve the appeal.
      Upon request, the Faculty Affairs Committee may share summaries of testimony and other information examined by the Committee with both the student and the instructor. Certain information, however, may be redacted from materials forwarded to the student and instructor to maintain other students' rights subject to protection under the Family Educational Rights and Privacy Act (FERPA), or other state and federal law.
      Based on its investigation, the Faculty Affairs Committee will determine whether the grade should be revised. The decision rendered will be either:
      i The original grading decision is upheld, or
      ii Sufficient evidence exists to indicate a grade has been assigned unfairly.
         In this latter case, the Faculty Affairs Committee will assign the student a new grade for the course. The Committee's written decision and supporting documentation will be delivered to the President of the Faculty Senate, the Graduate Dean, the student, the instructor, and the instructor's Department Head/Division Director no later than 25 business days following the Senate's receipt of the grade appeal. The Faculty Affairs Committee's decision shall constitute the final decision of the grade appeal. There is no further internal appeal available to the parties.

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

Graduation

All students expecting to graduate must apply to graduate in Trailhead.

Graduation application deadlines are scheduled well in advance of the date of Commencement to allow time for commencement preparation. Students who submit applications after the stated deadline cannot be guaranteed a diploma dated for that graduation, and cannot be assured inclusion in the graduation program or ceremony. Graduation applications are accepted only for students who have previously submitted to, and had approved by the Office of Graduate Studies, the appropriate Advisor/Thesis Committee (thesis students only), Degree Audit form (all students), and Admission to Candidacy form (PhD candidates only) as applicable to the degree sought. Students earning more than one degree must submit the appropriate forms for each degree and apply to graduate for each degree.

Graduation Requirements

Registration

To graduate, students must be registered during the term in which they complete their program. An exception to this registration policy allows students to complete an early checkout by census day of the graduation semester. Early checkout is accepted by the Graduate School and allows students to graduate in a term, without registering;

- checkout by Summer I census to graduate in August or December and avoid summer & fall registration,
- checkout by Fall census to graduate in December and avoid fall registration, and
- checkout by Spring census to graduate in May and avoid spring registration.

Students not meeting this checkout deadline are required to register for an additional semester before the Graduate School will process their checkout request. For additional information, refer to https://www.mines.edu/graduate-studies/graduation-deadlines/.

Check-out

All graduating students must officially checkout of their degree program. Checkout forms will be sent by the Graduate Office after a student has applied to graduate in Trailhead and must be completed and returned by the established deadline. Students must register for the graduation term, unless the checkout process is completed by census day of the graduation term.

Awarding Degrees

The awarding of a degree is contingent upon the student's successful completion of all program requirements with at least a 3.000 cumulative GPA before the date of graduation. Students who fail to graduate at the time originally anticipated must reapply for the next graduation before the appropriate deadline date stated on the Graduate School website.

Students who have completed all of their degree requirements by the early check-out deadline or at least 4 weeks prior to the standard check-out deadline can, if necessary, request a letter from the Graduate Office certifying the completion of their programs. The student must have applied to graduate for the current or next graduation, met all the degree requirements and have no holds. Degrees are not awarded during the early check-out time-frame, so for any student who is checking out early, the diploma and transcripts will show the date of the actual graduation and the degree will not show as being awarded until after degrees have been awarded for that term.

- December Early Check-Out in August/September: Degrees awarded in December/January
- May Early Check-Out in December/January: Degrees awarded in May
- August Early Check-Out in May: Degrees awarded in August/September

Degrees for all students, including those who check-out early, will be awarded within 10 business days after the commencement ceremony of the term in which the student applied to graduate, or for August graduates, 10 business days after summer II Physics courses end.

Commencement

Commencements are held in December and May. Students graduating in August may walk in the December graduation ceremony. Students eligible to graduate at these times are expected to attend their respective graduation exercises and must apply to graduate by the stated deadlines to be eligible to walk in the appropriate commencement ceremony. Students who do not apply to graduate by the stated deadlines, may not be allowed to walk in the commencement ceremony. The exception is non-thesis students graduating in August, may be allowed to walk in the May ceremony if all of the following are met: the student has less than 6 credits to complete in the summer, the student has applied to graduate in May and the student has consulted with the Mines Event Planner about the exception. Students in thesis-based degree programs may not, under any circumstances, attend graduation exercises before completing all degree requirements.

Diplomas, Transcripts and Letters of Completion

Diplomas, transcripts, and letters of completion will not be released by the School for any student or graduate who has an unsettled obligation of any kind to the School. Diplomas and transcripts will be available through the Registrar's Office after degrees have been awarded. Students who check-out early may request a Letter of Completion from the Office of Graduate Studies, but these letters will only be sent if requested at least 4 weeks prior to the commencement ceremony. Requests for a Letter of Completion after that time will not be accepted, so students will need to order the diploma or transcripts, as needed.

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

The deadline to apply to graduate and participate in commencement is Census Day 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 Census Day and at least 5 weeks prior to the commencement ceremony for the appropriate semester, may be made in writing and will be considered by the Office of Graduate Studies. 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 hour 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 check-out deadlines.

No graduate student will be added to a graduation or commencement when the request is made within less than 5 weeks to the commencement ceremony.

Public Access to Graduate Thesis

The award of a thesis-based graduate degree is conditioned on the student uploading his or her completed thesis in the Electronic Thesis and Dissertation system to ensure its availability to the public. Although the student retains the copyright in the thesis, by uploading the thesis in the electronic system, the student assigns a perpetual, non-exclusive, royalty-free license to Mines to permit Mines to copy the thesis and allow the public reasonable access to it.

Under special circumstances, Mines may agree to include proprietary research in a graduate student’s thesis. The nature and extent of the proprietary research reported in the thesis must be agreed upon in writing by the principal investigator and the student, and must be specified when the thesis or dissertation is uploaded into the electronic system.

In some cases, the proprietary nature of the underlying research may require the school to delay public access to the completed thesis for a limited period of time. In no case will public access to the thesis be denied for more than 12 months from the date the thesis or dissertation is published by the electronic system.

Unsatisfactory Academic Performance

Unsatisfactory Academic Progress Resulting in Probation or Discretionary Dismissal

A student's progress toward successful completion of a graduate degree shall be deemed unsatisfactory if any of the following conditions occur:

- Failure to maintain a cumulative grade point average of 3.0 or greater (see Graduate Grading System section);
- Receipt of an "Unsatisfactory Progress" grade for research; or
- Receipt of an "Unsatisfactory Progress" recommendation from:
  - the head or director of the student's home department or division,
  - the student's thesis committee, or
  - a departmental committee charged with the responsibility of monitoring the student's progress.

Unsatisfactory academic progress on the part of a graduate student shall be reported to the Graduate Dean in a timely manner. Students making unsatisfactory progress by any of the measures listed above are subject to discretionary dismissal according to the procedure outlined below.

In addition, students in thesis-based degree programs who are not admitted to candidacy within the time limits specified in this Catalog may be subject to immediate mandatory dismissal according to the procedure outlined below. Failure to fulfill this requirement must be reported to the Graduate Dean in a timely manner by the department head or division/program director.

Probation and Discretionary Dismissal Process and Procedure

Probation

The first semester on academic probation, the student will be notified by the Graduate Dean and asked to consult with his/her advisor. The notation on the student's transcripts will indicate that the student is on probation. To have the probation notation removed from the transcripts, the student must address the issue that caused the academic probation (i.e. bring GPA to a 3.0 or above, not receive a PRU, or address the issue from the department) within one semester. Students who do not address the issue after one semester will have the academic probation notation remain on the transcripts.

Discretionary Dismissal

The second semester on academic probation (not necessarily a consecutive semester) will result in discretionary dismissal. The Graduate Dean will notify the student in a timely manner and invite him or her to submit a written remedial plan, including performance milestones and deadlines, to correct the deficiencies that caused or contributed to the student's unsatisfactory academic progress. The remedial plan, which must be approved by the student's faculty advisor and the department head, division or program director, shall be submitted to the Dean no later than 10 business days from the date of official notification to the student of the potential discretionary dismissal. If the Dean concludes that the remedial plan is likely to lead to successful completion of all degree requirements within an acceptable time frame, the Dean may halt the discretionary dismissal process and allow the student to continue working toward his or her degree. If the Dean concludes that the remedial plan is inadequate, or that it is unlikely to lead to successful completion of all degree requirements within an acceptable time frame, the Dean shall notify the student of his or her discretionary dismissal and inform the student of his or her right to appeal the dismissal as outlined below. Students who have a second semester on academic probation will have the academic probation notation remain on the transcripts for the remainder of the academic career.

If the student fails to meet the conditions of the remedial plan, the student will be subject to mandatory dismissal.

Unsatisfactory Academic Performance Resulting in Mandatory Dismissal

Unsatisfactory performance as gauged by any of the following measures shall result in immediate, mandatory dismissal of a graduate student:

1. Failure to successfully defend the thesis after two attempts;
2. Failure to be admitted to candidacy; or
3. Failure by a student subject to discretionary dismissal to achieve a performance milestone or meet a deadline contained in his or her remedial plan.

The Graduate Dean shall be notified promptly of any situation that may subject a student to mandatory dismissal. In this event, the Dean shall notify the student of his or her dismissal and inform the student of his or her right to appeal the dismissal as outlined below.

Students who have been notified of mandatory dismissal will have 10 business days to appeal for extenuating circumstances or withdraw from school.

Students who have an appeal for extenuating circumstances approved by the faculty committee will be reinstated in the same degree program and will be allowed to continue with his/her studies as a graduate student. If an appeal is denied, the dismissal will stand.

Students who withdraw or are dismissed, may request re-admission to either the same program or a different degree program by submitting a full application for admission to the Office of Graduate Studies. The application will be reviewed through the normal admission process. To return, the student will need to be re-admitted into a degree program.

If a student who has been reinstated or readmitted to his or her former degree program is subsequently found to be making unsatisfactory progress, the student will immediately be subject to mandatory dismissal.

Appeal Procedures

Both mandatory and discretionary dismissals may be appealed by a graduate student pursuant to this procedure. To trigger review hereunder, an appeal must:

1. Be based on extenuating circumstances and/or irregularities in process. Examples of extenuating circumstances and/or irregularities in process along with suggested documentation can be found on the 2nd page of the Graduate Student Dismissal Appeal form (https://www.mines.edu/graduate-studies/wp-content/uploads/sites/60/2017/11/GS-Dismissal-Appeal-Form.xlsx).
2. Be submitted using the Graduate Student Dismissal Appeal form.
3. Include a description of the matter being appealed, supporting documentation, and a plan for successful completion of the degree program.

4. Be filed with the Office of Graduate Studies, c/o the Graduate Dean, no later than 10 business days from the date upon which the student received official notification from the Dean regarding his or her dismissal.

Upon receipt of a timely appeal of a discretionary or mandatory dismissal, the Graduate Dean will review the stated grounds for the appeal. If the Dean determines that the appeal satisfies the conditions required for review, the Dean will request that the Faculty Senate appoint a review committee comprised of three tenured faculty members who are not members of the student's home or minor (if applicable) department or division. The review committee shall review the student's appeal and issue a written recommendation thereon to the Dean within 10 business days. During the course of performing this function, the committee may:

1. Interview the student, the student's advisor, and, if appropriate, the student's thesis committee;
2. Review all documentation related to the appeal under consideration;
3. Secure the assistance of outside expertise, if needed; and
4. Obtain any other relevant information necessary to properly consider the appeal.

If the Dean determines that the appeal submitted does not have the required documentation showing sufficient extenuating circumstances, then the appeal will not be accepted and the student's dismissal will stand.

The authority to render a final decision regarding all graduate student appeals filed hereunder shall rest with the Graduate Dean.

Exceptions and Appeals

Academic Policies and Requirements

Academic policies and requirements are included in the Catalog on the authority of the Mines Board of Trustees as delegated to the Faculty Senate. These include matters such as degree requirements, grading systems, thesis and dissertation standards, admission standards and new and modified degree programs, certificates, minors and courses. No Mines administrator, faculty or staff member may change, waive or grant exceptions to such academic policies and requirements without approval of the Graduate Council, the Senate and/or the Board of Trustees as appropriate.

Administrative Policies and Procedures

Administrative Policies and Procedures are included in this Catalog on the authority of the Mines Board of Trustees as delegated to the appropriate administrative office. These include (but are not limited to) matters such as student record keeping, thesis and dissertation formats and deadlines, registration requirements and procedures, assessment of tuition and fees, and allocation of financial aid. The Graduate Dean may waive or grant exceptions to such administrative policies and procedures as warranted by the circumstances of individual cases.

Any graduate student may request a waiver or exception by the following process:

1. Contact the Office of Graduate Studies to determine whether a standard form exists. If so, complete the form. If a standard form does not exist, prepare a memo with a statement of the request and a discussion of the reasons why a waiver or exception would be justified.
2. Have the memo or the form approved by the student's advisor and department head or division director, then submit it to the Graduate Dean.
3. If the request involves academic policies or requirements, the Graduate Dean will request Graduate Council approval at the Council's next regularly scheduled meeting.
4. The Graduate Dean will notify the student of the decision. The student may file a written appeal with the Provost within 10 business days of being notified of the decision. The Provost will investigate as appropriate to the issue under consideration and render a decision. The decision of the Provost is final.

1. At the next graduate Council meeting, the Dean will notify the Graduate Council of the request, the decision and the reasons for the decision. If the Graduate Council endorses the decision, then any other student in the same situation having the same justification can expect the same decision.

Tuition, Fees, Financial Assistance

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

Graduate Tuition

The official tuition and approved charges for the 2018-2019 academic year will be available prior to the start of the 2018-2019 academic year located at: https://inside.mines.edu/F-A-Budget-Update

Fees

The official fees, approved charges, and fee descriptions for the 2018-2019 academic year will be available prior to the start of the 2018-2019 academic year and can be found at: https://inside.mines.edu/F-A-Budget-Update.

Please note that graduate students who register for undergraduate courses to satisfy deficiencies may be assessed the same fee that an undergraduate student would pay.

Payments and Refunds

Payment Information

A student is expected to complete the registration process, including the payment of tuition and fees, before attending class. Students should pay online through Trailhead, pay in person at the cashier's office in the Ben Parker Student Center, or mail payments to:

Cashier Colorado School of Mines
1500 Illinois St.
Golden, CO 80401-1869 or

Please write your student ID on payment.

Late Payment Penalties

A penalty will be assessed against a student if payment is not received in full by the official day of registration. The penalty is described in the schedule of courses for each semester. If payment is not completed by the sixth week of class, the student may be officially withdrawn from classes.

Financial Responsibility

Registration for classes at CSM implies an obligation by the student to meet all related financial responsibilities in a timely manner. Students who do not fulfill their financial obligations according to published deadlines are subject to the following: late payment penalties accrued on any outstanding balance, and the withholding of transcripts. Past due accounts will be turned over to Colorado Central Collection Services in accordance with Colorado law. Collection costs will be added to the student's account, and delinquencies may be reported to national credit bureaus.

Encumbrances

A student will not be permitted to register for future classes, to graduate, or to get an official transcript of his academic record while indebted in any way to CSM.

Refunds

Refunds for tuition and fees are made according to the following policy:

The amount of tuition and fee assessment 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 the withdrawal 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 the withdrawal from a course or courses is made after the add/drop period, and the student does not officially withdraw from school, no adjustment in charges will be made.
- If the withdrawal from courses is made after the add/drop period, and the student withdraws from school, tuition and fee assessments will be reduced according to the following schedule:
  - Within the 7 calendar days following the end of the add/drop period, 60 percent reduction in charges.
  - Within the next following 7 calendar days, a 40 percent reduction in charges.
  - Within the next following 7 calendar days, a 20 percent reduction in charges.
  - After that period, no reduction of charges will be made.

The schedule above applies to the Fall and Spring semesters. The time periods for the Summer sessions - Field and Summer - will be adjusted in proportion to the reduced number of days in these semesters. Exceptions to this policy may be granted under extraordinary extenuating circumstances; requests should be initiated with the Dean of Graduate Studies.

Room and board refunds are prorated 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.

PLEASE NOTE: Students receiving federal financial aid under the Title IV programs may have a different refund determined as required by federal law or regulations.

Financial Assistance for Graduate Studies

Graduate study is a considerable investment of time, energy, and money by serious students who expect a substantial return not only in satisfaction but also in future earnings. Applicants are expected to weigh carefully the investment they are willing to make against expected benefits before applying for admission.

Students are also expected to make full use of any resources available, including personal and loan funds, to cover expenses, and the School can offer some students financial aid through graduate research and teaching assistantships and through industry, state, and federal fellowships.

Purpose of Financial Aid

The Graduate School's limited financial aid is used

1. To give equal access to graduate study by assisting students with limited personal resources;
2. To compensate graduate students who teach and do research;
3. To give an incentive to exceptional students who can provide academic leadership for continually improving graduate programs.

Employment Restrictions and Agreements

Students who are employed full time or who are enrolled part time are not eligible for financial aid through the Graduate School.

Students who are awarded assistant-ships must sign an appointment agreement, which gives the terms of appointment and specifies the amount and type of work required. Graduate assistants who hold regular appointments are expected to devote all of their efforts to their educational program and may not be otherwise employed without the written permission of their supervisor and the Graduate Dean. Students with assistant-ships during the academic year must be registered as full time. During the summer session they must be registered for a minimum of three credit hours, unless they qualify for the summer research registration exception. Please see http://www.mines.edu/graduate_admissions for details on summer registration exception eligibility.

Aid Application Forms

New students interested in applying for financial aid are encouraged to apply early. Financial aid forms are included in Graduate School application packets and may be filled out and returned with the other application papers.

Graduate Fellowships

The departments and divisions may award fellowships based on the student's academic performance.

Graduate Student Loans

Federal student loans are available for graduate students who need additional funding beyond their own resources and any assistant-ships or fellowships they may receive. The Free Application for Federal Student Aid (FAFSA) must be completed to apply for these loan funds. Students must be degree seeking, taking courses towards their degree and attending at least part-time (4.5 hrs) per semester (including summer) to be eligible. Degree seeking students who are approved for reduced registration (4 hrs/semester fall and spring and 3 hrs summer) are also eligible.

Specific information and procedures for filing the FAFSA can be found on the Financial Aid Office web site at http://finaid.mines.edu. The Financial Aid Office telephone number is 303-273-3301, and the email address is finaid@mines.edu.

Satisfactory Academic Progress for Federal Student Loans and Colorado Grad Grant

Students receiving assistance from federal or Colorado funds must make satisfactory academic progress toward their degree. Satisfactory progress is defined by maintaining adequate pace towards graduation and maintaining a 3.0 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 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. In addition, if students receive grades of F, PRU or INC in all of their courses, their future financial aid eligibility will be terminated without a warning period. 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.

Late Fee for Application to Graduate after Stated Deadlines - $250 Beginning Fall 2014

The deadline to apply to graduate and participate in commencement is Census Day 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 Census Day (and before Graduation Salute for the appropriate semester) may be made in writing and will be considered by the Office of Graduate Studies.

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 hour 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 check-out 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 graduate student will be added to a graduation or commencement when the request is made after Graduation Salute.

Graduate Departments and Programs

Colorado School of Mines offers post-baccalaureate programs leading to the awarding of Graduate Certificates, Professional Master degrees, thesis and non-thesis Master of Science degrees, non-thesis Master of Engineering degrees, and Doctor of Philosophy degrees. This section describes these degrees and explains the minimum institutional requirements for each. Students may apply to, and be admitted in, multiple graduate degrees simultaneously. In this case, a student may use the same graduate course credits to satisfy the degree requirements for each degree.

Students enrolled simultaneously and/or sequentially in two Mines Master degree programs may double count up to half of the course credits required for the Master degree program with the smallest course credit hour requirement toward both degree programs. Before the Office of Graduate Studies will count these credits toward each degree requirement, the student must obtain written permission to do so from each department, division or program granting degree. This permission should be submitted with the student's Degree Audit form and should clearly indicate that each degree program is aware that the specific credits are being counted toward the requirements of multiple master's degrees. For thesis-based students this permission should be provided by the student's thesis committee and department/division chair. For non-thesis and certificate programs, permission should be obtained from advisors and department/division chairs.

Students simultaneously and/or sequentially enrolled in a Master degree and Doctoral degree may, with departmental approval double count course credits toward each degree without limit. Approval to count credits towards a Master's degree and PhD will be indicated by the committee's and department/division chair's signature on the Degree Audit form.

Course credits may never be applied toward more than two graduate degrees.

I. Responsible Conduct of Research Requirement

All students supported at any time in their graduate career through the National Science Foundation (NSF), as research assistants, hourly employees or fellowship awardees, must complete training in the responsible conduct of research (RCR). This requirement is in addition to all other institutional and program requirements described below and in the appropriate program sections of this Catalog.

To satisfy the RCR requirement students must complete one of the following options:

- HASS565- Option available to all students
- SYGN502 - Option available to all students
- Chemistry Program Option - Option available only to students in the Chemistry program
- Physics program option: option available only to students with physics faculty advisors or co-advisors
- Chemical & Biological Engineering (CBE) option - Option available only to students in the CBE degree program

For additional information on program-specific options, contact the program.

By whatever means chosen, the NSF-RCR requirement must be completed prior to a candidate submitting the Degree Audit form. Students and advisors certify successful completion of the RCR requirement on the Degree Audit form.

II. Professional Programs

A. Graduate Certificate Program

Graduate Certificate Programs at Mines are designed to have selective focus, short time to completion and consist of course work only. For more information about specific professional programs, please refer to the "Graduate Degree Programs and Description of Courses" portion of this Catalog.

1. Academic Requirements

Each Graduate Certificate requires a minimum of 12 total credit hours. No more than 3 credit hours at the 400 level may be applied toward the minimum credit-hours requirement. All other credits must be at or above the 500 level. Students may not, on an individual basis, request credit hours be transferred from other institutions as part of the Certificate requirements. Some Graduate Certificates, however, may allow the application of specific, pre-approved transfer credits, or credits from other institutions with whom Mines has formal agreements for this purpose toward fulfilling the requirements of the Certificate. All courses applied to a Graduate Certificate are subject to approval by the program offering the certificate.

If a student has earned a Graduate Certificate and subsequently applies, and is accepted into a Master or PhD program at Mines, credits earned in the Certificate Program may, with the approval of the advanced degree program, be applied to the advanced degree subject to all the applicable restrictions on credit hours that may be applied toward fulfilling the requirements of the advanced degree.

2. Graduation Requirements

Full-time students must complete the following requirement within the first semester after enrolling into a Graduate Certificate degree program.

- complete all prerequisites and core curriculum course requirements of their program.

A list of prerequisites and core curriculum requirements for Graduate Certificate degrees is published by each program. When a student is admitted with deficiencies, the appropriate department head, division director or program director will provide the student with a written list of courses required to remove these deficiencies. This list will be given to the student no later than one week after the start of classes of his/her first semester in order to allow for adding/dropping courses as necessary.

Upon completion of the above-defined requirements, a student must submit a Degree Audit form and a completed Statement of Work Completion forms documenting satisfactory completion of the prerequisites and core curriculum requirements. The form must have the written approval of the program offering the Graduate Certificate.

B. Professional Master Program

Mines awards specialized, career-oriented non-thesis Master degrees with the title of "Professional Master (descriptive title)." These are custom-designed, interdisciplinary degrees, each with a curriculum meeting the career advancement needs of a particular group of professionals in a field that is part of CSM's role and mission. For more information about these programs, please refer to the "Graduate Degree Programs and Description of Courses" portion of this Catalog.

1. Academic Requirements

Each Professional Master degree consists of a minimum of 30 total credit hours. Students must complete at least 21 credit hours at Mines in the degree program. The remaining hours may be transferred into the program. Requests for transfer credit must be approved by the faculty according to a process defined by the student's home department or division. Transfer credits must not have been used as credit toward a Bachelor degree. The transfer limit includes Mines distance learning courses. Up to six credit hours of Special Topic or Independent Study may be in the form of project credits done on the job as an employee or as a graduate intern. If project credits are to be used, the project proposal and final report must be approved by a Mines faculty advisor, although direct supervision may be provided by the employer. Students must maintain a cumulative grade point average of 3.0 or better in Mines course work.

2. Graduation Requirements

Full-time students must complete the following requirement within the first calendar year after enrolling into a Professional Master degree program.

- complete all prerequisite and core curriculum course requirements of their program.

If students are admitted with deficiencies, the appropriate department heads, division directors or program directors will provide the students written lists of courses required to remove the deficiencies. These lists will be given to the students no later than one week after the start of classes of their first semester in order to allow them to add/drop courses as necessary. Completion of prerequisites and deficiencies will be monitored by the department.

Upon completion of the above defined requirements, students must submit a Degree Audit form documenting satisfactory completion of the core curriculum requirements. Deficiency and/or prerequisite courses may not be listed on the Degree Audit form. The form must have the written approval of all members of the advisor and thesis committee, if appropriate.

To graduate, all Professional Master students must submit all required forms, apply to graduate in Trailhead, and submit a completed checkout card and a completed Statement of Work Completion by the posted deadlines.

III. Master of Science and Master of Engineering Programs

A. General Requirements

Graduate study at Mines can lead to one of a number of thesis and non-thesis based Master's degrees, depending on the interests of the student. All Master's degree programs share the same academic requirements for grades and definition of minor programs.

1. Academic Requirements

A Master's degree at Mines requires a minimum of 30 total credit hours, with some degrees requiring additional credits. As part of this minimum 30 hours, departments and divisions are required to include a research or design experience supervised by Mines faculty. For more information about the specific research/design requirements, please refer to the appropriate department/division section of the "Graduate Degree Programs and Description of Courses" portion of this Catalog.

For non-thesis Master's degrees, students must complete at least 21 credit hours at Mines in the degree program. All other coursework credits may be completed as transfer credits into the degree program. For thesis Master's degrees, no more than 9 coursework credits may transfer.

The transfer credit limit includes any credits listed on a Mine's undergraduate transcript and/or any credits taken at another university, including credits taken under the Exchange Reciprocal Agreement. Transfer credits must not have been used as credit toward a Bachelor degree, must not be pre-requisites or deficiencies, must have a letter grade of C or better, must be graduate level credits and must be required for the degree. Requests for transfer credit must be approved by the faculty according to the process defined by a student's home department or division. All credits applied toward degree, except transfer credits, must be earned on campus. Students must maintain a cumulative grade point average of 3.0 or better in Mines course work.

2. Minor Programs

Students may choose to have a minor program or programs at the Master's level. A minor program may not be taken in the student's major area of study. A designated minor requires a minimum of 9 semester hours of graduate course work and must be approved by the student's advisor, home department head/division director, and a graduate faculty representative of the minor area of study. Less than half of the credit hours applied toward the minor degree program may be in the form of transfer credit hours. Transfer credit hours applied toward the minor are included as part of the overall transfer limitation applied to the degree as defined above.

3. Graduation Requirements

Full-time students must complete the following requirements within one calendar year of enrolling into the Master's degree program.

- have a thesis committee appointment form on file in the Office of Graduate Studies (thesis based students only), and
- complete all prerequisite and core curriculum course requirements of their department, division or program.

If students are admitted with deficiencies, the appropriate department heads, division directors or program directors will provide the students written lists of courses required to remove the deficiencies. These lists will be given to the students no later than one week after the start of classes of their first semester in order to allow them to add/drop courses as necessary. Completion of prerequisites and deficiencies will be monitored by the department.

Upon completion of the above defined requirements, students must submit a Degree Audit form documenting satisfactory completion of the core curriculum requirements. Deficiency and/or prerequisite courses may not be listed on the Degree Audit form. The form must have the written approval of all members of the advisor and thesis committee, if appropriate.

To graduate, all Master of Science and Master of Engineering students must submit all forms, apply to graduate in Trailhead, and submit a completed checkout form by the posted deadlines. In addition, thesis-based students must upload a content-approved thesis and have the formatting approved by the posted check-out deadlines.

B. Non-thesis Option

Non-thesis Master's degrees (both non-thesis Master of Science and Master of Engineering) are offered by a number of departments, divisions and programs. In lieu of preparing a thesis, non-thesis master's program students are required to complete a research or design experience taken as a special problem or as an independent study course. See the department/division section of the "Graduate Degree Programs and Description of Courses" portion of this Catalog for more information. Although non-thesis master's students are not assigned a Thesis Committee, students in this program are assigned a faculty advisor by the student's home department. The advisor is subject to approval by the Office of Graduate Studies.

C. Thesis Option

Thesis-based Master of Science degrees require completion of a satisfactory thesis and successful oral defense of this thesis. Academic credit toward completion of the thesis must include successful completion of no fewer than 6 credit hours of masters-level research credit. The thesis is expected to report on original research that results in new knowledge and/or techniques or on creative engineering design that applies state-of-the-art knowledge and techniques to solve an important problem. In either case, the thesis should be an exemplary product that meets the rigorous scholarship standards of the Colorado School of Mines. The student's faculty advisor and the Master's Thesis Committee must approve the program of study and the topic for the thesis. The format of the thesis must comply with the appropriate guidelines promulgated by the Office of Graduate Studies.

1. Faculty Advisor Appointment

When admitted, each thesis-based Master's student is assigned a faculty advisor by the department. Students who are assigned temporary advisors at admissions will work with their department to have a permanent advisor assigned. Master's students changing a temporary advisor to a permanent advisor or selecting a new advisor will need the new faculty advisor approved by the Office of Graduate Studies by the end of the second semester at Mines.

Advisors will provide advice regarding the student's thesis direction, research and selection of courses. To be approved by the Office of Graduate Studies, advisors must be designated as Mines graduate faculty. Please refer to the Faculty Handbook for a definition of what constitutes Mines graduate faculty. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors.

The Director of the degree program, often times the head of the student's home department or division, and the Graduate Dean must approve all faculty advisor appointments.

2. Thesis Committee

The Graduate Dean will approve a Thesis Committee whose members have been recommended by the student, the student's faculty advisor, the student's department head and whose members meet the minimum requirements listed below. Students should have a thesis committee approved by the end of their second semester.

This Committee will have a minimum of three voting members, including the student's advisor, who are familiar with the student's area of study.

1. Of these three (3) Committee members, two must be designated as Mines graduate faculty from the home department or, in the case of interdisciplinary degree programs, designated as Mines graduate faculty in an allied department.
2. The third member of the committee may be Mines faculty or an off campus member.
    - Off-campus members can be assigned to the Committee as the 3rd member or as additional members. If assigned as the 3rd member, the member must be a voting member. Off-campus members nominated for voting status on the committee request form must include a brief resume of their education and/or experience that demonstrates their competence to judge the quality and validity of the thesis. Such members also must agree to assume the same responsibilities expected of on-campus Committee members including, but not limited to, attendance at Committee meetings, review of thesis proposals and drafts and defense.
3. Additional members (more than the 3 required), either Mines faculty or off campus members may serve either with full voting status or in a non-voting capacity. Off-campus members with voting status assume all of the responsibilities of on-campus Committee members with respect to attendance of Committee meetings, review of thesis drafts and participation in oral examinations and thesis defense sessions.
4. If a thesis co-advisor is assigned, an additional member, Mines faculty or off campus member, must be added to the committee. Co-advisors must be voting members of the committee.
5. Students who choose to have a minor program at the Master's level must select a representative from their minor department of study to serve on the Thesis Committee. Minor representatives must be a designated as a Mines graduate faculty member in the Minor department.
6. A Thesis Committee Chairperson is designated by the student at the time he/she requests the formation of his/her thesis committee. The chairperson is responsible for leading all meetings of the thesis committee and for directing the student's thesis defense. In selecting a Thesis Committee chairperson, the following guidelines must be met:

- The chairperson cannot be the student's advisor or co-advisor and
- The chairperson must be a designated as a Mines graduate faculty member.

Shortly after its appointment, the Committee will meet with the student to hear a presentation of the proposed course of study and thesis topic. The Committee and the student must agree on a satisfactory program and the student must obtain the Committee approval of the written thesis proposal at least one semester prior to the thesis defense. The student's faculty advisor assumes the primary responsibility for monitoring the program and directing the thesis work. The award of the thesis-based Master's degree is contingent upon the student's researching and writing a thesis acceptable to the student's faculty advisor and Thesis Committee.

3. Thesis Defense

The student submits an initial draft of his or her thesis to the faculty advisor, who will work with the student on necessary revisions. Upon approval of the student's advisor, the revised thesis is circulated to the

Thesis Committee members at least one week prior to the oral defense of the thesis. The oral defense of the thesis is scheduled during the student's final semester of study. Students must be registered to defend. This defense session, which may include an examination of material covered in the student's course work, will be open to the public.

Following the defense, the Thesis Committee will meet privately to vote on whether the student has successfully defended the thesis. Three outcomes are possible: the student may pass the oral defense; the student may fail the defense; or the Committee may vote to adjourn the defense to allow the student more time to address and remove weaknesses or inadequacies in the thesis or underlying research. Two negative votes will constitute a failure regardless of the number of Committee members present at the thesis defense. In the event of either failure or adjournment, the Chair of the Thesis Committee will prepare a written statement indicating the reasons for this action and will distribute copies to the student, the Thesis Committee members, the student's department head and the Graduate Dean. In the case of failure or adjournment, the student may request a re-examination, which must be scheduled no less than one week after the original defense. A second failure to defend the thesis satisfactorily will result in the termination of the student's graduate program.

Upon passing the oral defense of thesis or report, the student must make any corrections in the thesis required by the Thesis Committee. The final, corrected copy and an executed signature page indicating approval by the student's advisor and department head must be submitted to the Office of Graduate Studies for format approval. (Format instructions are available on the Office of Graduate Studies website and should be thoroughly read before beginning work on the thesis.)

4. Time Limitations

A candidate for a thesis-based Master's degree must complete all requirements for the degree within five years of the date of admission into the degree program. Time spent on approved leaves of absence is included in the five-year time limit. Candidates not meeting the time limitation will be notified and withdrawn from their degree programs.

Candidates may apply for a one-time extension of this time limitation. This application must be made in writing and approved by the candidate's advisor, thesis committee, department and Graduate Dean. The application must include specific timelines and milestones for degree completion. If an extension is approved, failure to meet any timeline or milestone will trigger immediate withdrawal from the degree program.

If the Graduate Dean denies an extension request, the candidate may appeal this decision to the Provost. The appeal must be made in writing, must specifically state how the candidate believes the request submitted to the Dean met the requirements of the policy, and must be received no later than 10 business days from the date of notification of the Dean's denial of the original request.

If a candidate is withdrawn from a degree program through this process (i.e., either by denial of an extension request or failure to meet a timeline or milestone) and wishes to re-enter the degree program, that candidate must formally reapply for readmission. The program has full authority to determine if readmission is to be granted and, if granted to fully re-evaluate the Candidate's work to date and determine its applicability to the new degree program.

IV. Doctor of Philosophy

A. Credits, Hour and Academic Requirements

The Doctor of Philosophy degree requires completion of a minimum of 72 semester hours beyond the Bachelor degree. At least 24 semester hours must be research credits earned under the supervision of a Mines faculty advisor and at least 18 credit hours of course work must be applied to the degree program. Course requirements for each department or division are contained in the "Graduate Degree Programs and Description of Courses" section of this Catalog.

The degree also requires completion of a satisfactory doctoral thesis and successful oral defense of this thesis. The Doctoral Thesis is expected to report on original research that results in a significant contribution of new knowledge and/or techniques. The student's faculty advisor and the Doctoral Thesis Committee must approve the program of study and the topic for the thesis.

B. Residency Requirements

Doctoral students must complete a residency requirement during the course of their graduate studies. The purpose of this requirement is to:

- require students to become engaged in extended and focused research activities under the direct supervision of Mines faculty;
- allow students to become immersed in the culture of an academic environment;
- allow students to engage in the professional activities associated with their research discipline;
- ensure students have access to the research tools and expertise needed for their chosen research activity;
- ensure the conduct of cutting-edge research with the expectation that this research will be completed in a timely fashion so that it is still relevant to the larger research community;
- provide Mines faculty with the ability to directly evaluate the research and academic credentials of a student and as such protect the integrity of the degree, department and the institution;
- ensure the research produced by students claiming a Mines degree is actually the product of Mines' intellectual environment; and
- make it clear that the intellectual property developed while in the degree program is the property of Mines as defined in the Faculty Handbook.

The residency requirement may be met by completing two semesters of full-time registration at Mines. The semesters need not be consecutive. Students may request an exception to the full-time registration requirement from the Graduate Dean. Requests for exception must be in writing, must clearly address how the student's learning experience has met the goals of the residency requirement, as articulated above, and must be submitted by both the student and the student's thesis advisor and be approved by the student's Department Head/Division Director.

C. Transfer of Credits

Up to 24 semester hours of graduate-level course work may be transferred from other institutions toward the PhD degree subject to the restriction that those courses must not have been used as credit toward a Bachelor degree, must not be prerequisites or deficiencies, must have a letter grade of C or better and must be graduate level credits. Requests for transfer credit must be approved by the faculty according to a process defined by the student's home department or division. Transfer credits are not included in calculating the student's grade point average at Mines.

In lieu of transfer credit for individual courses defined above, students who enter the PhD program with a thesis-based Master's degree from another institution may transfer up to 36 semester hours in recognition of the course work and research completed for that degree. The request must be approved by the faculty according to a process defined by the student's home department or division.

D. Faculty Advisor Appointments

When admitted, each doctoral student is assigned a faculty advisor by the department. Students who are assigned temporary advisors at admissions will work with their department to have a permanent advisor assigned. PhD students changing a temporary advisor to a permanent advisor or selecting a new advisor will need the new faculty advisor approved by the Office of Graduate Studies by the end of the second semester at Mines.

Advisors will advise students with respect to the student's thesis direction, research and selection of courses. Advisors must be designated as a Mines graduate faculty member. Please refer to the Faculty Handbook for a definition of what constitutes Mines graduate faculty. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors.

The Director of the doctoral degree program, often times the head of the student's home department or division, and the Graduate Dean must approve all faculty advisor appointments.

E. Minor Programs

Students may choose a minor program or programs at the PhD level consisting of 12 course credits in the minor program. The student's faculty advisor and Doctoral Thesis Committee, including an appropriate minor committee member as described below, approve the course selection and sequence in the selected minor program. Students may choose to complete multiple minor programs. Each program must consist of at least 12 credit hours approved by the faculty advisor and Doctoral Thesis Committee, including the appropriate minor committee members. Less than half of the credit hours applied toward the minor degree program may be in the form of transfer credit hours. Transfer credit hours applied toward a minor are included as part of the overall transfer limitation applied to the degree as defined above.

F. Doctoral Thesis Committees

The Graduate Dean will approve a Doctoral Thesis Committee whose members have been recommended by the student, the student's faculty advisor, the student's department head and whose members meet the minimum requirements listed below. Students should have a thesis committee approved by the end of their second year of study. This Committee must have a minimum of four voting members that fulfill the following criteria:

1. The Committee must include an advisor who meets the qualifications defined above. If two advisors are appointed, both shall be voting members of the Committee.
2. The Committee must have at least two voting members knowledgeable in the technical areas of the thesis in addition to the advisor(s) and who are designated as Mines graduate faculty.
3. The fourth, required member of the Committee must be designated as a Mines graduate faculty member, may not be an advisor, co-advisor, or minor representative, and must be from outside of the student's doctoral degree program, home department and minor program area(s) – if appropriate. This committee member acts as Thesis Committee Chairperson.
4. If a thesis co-advisor is assigned, an additional member, Mines faculty or off campus member, must be added to the committee. Co-advisors must be voting members of the committee.
5. If a minor field is designated, an additional committee member must be included who is an expert in that field. Minor representatives must be designated as Mines graduate faculty members who are participating faculty in the minor program area. If multiple minor programs are pursued, each must have a committee representative as defined above.
6. Off-campus representatives may serve as additional committee members. If off-campus members are nominated for voting status, the committee request form must include a brief resume of their education and/or experience that demonstrates their competence to judge the quality and validity of the thesis. Such members also must agree to assume the same responsibilities expected of on-campus Committee members including, but not limited to, attendance at Committee meetings, review of thesis proposals and drafts, and participation in oral examinations and defense.

Shortly after its appointment, the Doctoral Thesis Committee meets with the student to hear a presentation of the proposed course of study and thesis topic. The Committee and student must agree on a satisfactory program. The student's faculty advisor then assumes the primary responsibility for monitoring the program, directing the thesis work, arranging qualifying examinations, and scheduling the thesis defense.

Upon completion of all prerequisite and core curriculum course requirements of their department division or program, students must submit a Degree Audit form documenting satisfactory completion of the core curriculum requirements. Deficiency and/or prerequisite courses may not be listed on the Degree Audit form. The form must have the written approval of all members of the advisor and thesis committee, if appropriate.

G. Admission to Candidacy

Full-time students must complete the following requirements within the first two calendar years after enrolling into the PhD program.

- have an approved thesis committee form on file in the Graduate Office;
- complete all prerequisite and core curriculum course requirements of their department, division or program;
- demonstrate adequate preparation for, and satisfactory ability to conduct, doctoral research; and
- be admitted into full candidacy for the degree.

If students are admitted with deficiencies, the appropriate department heads, division directors or program directors will provide the students written lists of courses required to remove the deficiencies. These lists will be given to the students no later than one week after the start of classes of their first semester in order to allow them to add/drop courses as necessary. Completion of prerequisites and deficiencies will be monitored by the department.

Each program also defines the process for determining whether its students have demonstrated adequate preparation for, and have satisfactory ability to do, high-quality, independent doctoral research in their specialties. These requirements and processes are described under the appropriate program headings in the section of this Catalog on Graduate Degree Programs and Description of Courses.

To graduate, all PhD students must submit all required paperwork, apply to graduate in Trailhead, submit a completed checkout card and complete the Survey of Earned Doctorate by the posted deadlines. In addition, PhD students must upload a content approved thesis and have the formatting approved by the posted check-out deadlines.

H. Thesis Defense

The doctoral thesis must be based on original research of excellent quality in a suitable technical field, and it must exhibit satisfactory literary merit. In addition, the format of the thesis must comply with guidelines promulgated by the Office of Graduate Studies. (Formatting requirements are listed on the Office of Graduate Studies website and students should thoroughly read these guidelines before beginning work on the thesis.)

The thesis topic must be submitted in the form of a written proposal to the student's faculty advisor and the Committee. The Committee must approve the proposal at least one year before the thesis defense.

The student's faculty advisor is responsible for supervising the student's research work and consulting with other Doctoral Thesis Committee members on the progress of the work. The advisor must consult with the Committee on any significant change in the nature of the work. The student submits an initial draft of his or her thesis to the advisor, who will work with the student on necessary revisions. Upon approval of the student's advisor, the revised thesis is distributed to the other members of the Committee at least one week prior to the oral defense of the thesis.

The student must pass an oral defense of his or her thesis during the final semester of studies. Students must be registered to defend. This oral defense may include an examination of material covered in the student's course work. The defense will be open to the public.

Following the defense, the Doctoral Thesis Committee will meet privately to vote on whether the student has successfully defended the thesis. Three outcomes are possible: the student may pass the oral defense; the student may fail the defense; or the Committee may vote to adjourn the defense to allow the student more time to address and remove weaknesses or inadequacies in the thesis or underlying research. Two negative votes will constitute a failure regardless of the number of Committee members present at the thesis defense. In the event of either failure or adjournment, the Chair of the Doctoral Thesis Committee will prepare a written statement indicating the reasons for this action and will distribute copies to the student, the Thesis Committee members, the student's department head and the Graduate Dean. In the case of failure, the student may request a re-examination, which must be scheduled no less than one week after the original defense. A second failure to defend the thesis satisfactorily will result in the termination of the student's graduate program.

Upon passing the oral defense of thesis, the student must make any corrections in the thesis required by the Doctoral Thesis Committee. The final, corrected copy and an executed signature page indicating approval by the student's advisor and department head must be submitted to the Office of Graduate Studies for format approval.

I. Time Limitations

A candidate for a thesis-based Doctoral degree must complete all requirements for the degree within nine years of the date of admission into the degree program. Time spent on approved leaves of absence is included in the nine-year time limit. Candidates not meeting the time limitation will be notified and withdrawn from their degree programs.

Candidates may apply for a one-time extension of this time limitation. This application must be made in writing and approved by the candidate's advisor, thesis committee, department and Graduate Dean. The application must include specific timelines and milestones for degree completion. If an extension is approved, failure to meet any timeline or milestone will trigger immediate withdrawal from the degree program.

If the Graduate Dean denies an extension request, the candidate may appeal this decision to the Provost. The appeal must be made in writing, must specifically state how the candidate believes the request submitted to the Dean met the requirements of the policy, and must be received no later than 10 business days from the date of notification of the Dean's denial of the original request. The Provost's decision is final.

If a candidate is withdrawn from a degree program through this process (i.e., either by denial of an extension request or failure to meet a timeline or milestone) and wishes to reenter the degree program, that candidate must formally reapply for readmission. The program has full authority to determine if readmission is to be granted and, if granted to fully re-evaluate the Candidate's work to date and determine its applicability to the new degree program.

V. Roles and Responsibilities of Committee Members and Students

Below, are the roles and expectations Mines has of faculty as members of Thesis Committees and of students engaged in research-based degree programs.

Thesis Advisor(s)

The Thesis Advisor has the overall responsibility for guiding the student through the process of the successful completion of a thesis that fulfills the expectations of scholarly work at the appropriate level as well as meets the requirements of the Department/Division and the School. The Advisor shall:

- be able and willing to assume principal responsibility for advising the student;
- have adequate time for this work and be accessible to the student;
- provide adequate and timely feedback to both the student and the Committee regarding student progress toward degree completion;
- guide and provide continuing feedback on the student's development of a research project by providing input on the intellectual appropriateness of the proposed activities, the reasonableness of project scope, acquisition of necessary resources and expertise, necessary laboratory or computer facilities, etc.;
- establish key academic milestones and communicate these to the student and appropriately evaluate the student on meeting these milestones.

Regular Committee Member

With the exception of the student's advisor, all voting members of the Thesis Committee are considered Regular Committee Members. The Regular Committee Member shall:

- have adequate time to assume the responsibilities associated with serving on a student's Thesis Committee;

- be accessible to the student (at a minimum this implies availability for Committee meetings and availability to participate in a student's qualifying/comprehensive examinations – as dictated by the practices employed by the degree program – and the thesis defense);
- ensure that the student's work conforms to the highest standards of scholarly performance within the discipline, within the expertise provided by the Committee member;
- provide advice to both the student and the student's advisor(s) on the quality, suitability and timeliness of the work being undertaken;
- approve the student's degree plan (e.g., courses of study, compliance with program's qualifying process, thesis proposal, etc.), assuring that the plan not only meets the intellectual needs of the student, but also all institutional and program requirements;
- review dissertation drafts as provided by the student and the advisor and provide feedback in a timely fashion; and
- participate in, and independently evaluate student performance in the final thesis defense.

Minor Field Committee Representative

In addition to the responsibilities of a Regular Committee Member, the Minor Field Committee Representative has the following added responsibilities:

- provide advice for, and approval of coursework required as part of a student's minor degree program in a manner that is consistent with institutional and minor program requirements;
- participate in, as appropriate, the student's qualifying and comprehensive examination process to certify completion of minor degree requirements; and
- work individually with the student on the thesis aspects for which the Minor Committee member has expertise.

Thesis Committee Chairperson

In addition to the responsibilities of a Regular Committee Member, the Chairperson of Committee has the following added responsibilities:

- chair all meetings of the Thesis Committee including the thesis defense;
- represent the broad interests of the Institution with respect to high standards of scholarly performance;
- represent the Office of Graduate Studies by ensuring that all procedures are carried out fairly and in accordance with institutional guidelines and policies; and
- ensure that any potential conflicts of interest between student, advisor or any other committee member are effectively identified and managed.

Student Responsibilities

While it is expected that students receive guidance and support from their advisor and all members of the Thesis Committee, the student is responsible for actually defining and carrying out the program approved by the Thesis Committee and completing the thesis/dissertation. As such, it is expected that the student assumes a leadership role in defining and carrying out all aspects of his/her degree program and thesis/dissertation project. Within this context, students have the following responsibilities:

- to formally establish a Thesis Advisor and Committee by the end of their first year of residence in their degree program;
- to call meetings of the Thesis Committee as needed;
- to actively inform and solicit feedback from the student's Advisor and Committee on progress made toward degree;
- to respond to, and act on feedback from the student's Advisor and Committee in a timely and constructive manner;
- to understand and then apply the institutional and programmatic standards related to the ethical conduct of research in the completion of the student's thesis/dissertation; and
- to know, understand and follow deadlines defined by the institution and the degree program related to all aspects of the student's degree program.

VI. Combined Undergraduate/Graduate Degree Programs

A. Overview

Many degree programs offer Mines undergraduate students the opportunity to begin work on a Graduate Certificate, Professional Master’s Degree, Master’s Degree, or Doctoral Degree while completing the requirements for their Bachelor’s Degree. These combined Bachelors-Masters/Doctoral programs have been created by Mines faculty in those situations where they have deemed it academically advantageous to treat undergraduate and graduate 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.

The combined programs at Mines offer several advantages to students who choose to enroll in them:

1. Students can earn a graduate degree in their undergraduate major or in a field that complements their undergraduate major.
2. Students who plan to go directly into industry leave Mines with additional specialized knowledge and skills which may allow them to enter their career path at a higher level and advance more rapidly. Alternatively, students planning on attending graduate school can get a head start on their graduate education.
3. Students can plan their undergraduate electives to satisfy prerequisites, thus ensuring adequate preparation for their graduate program.
4. Early assignment of graduate advisors permits students to plan optimum course selection and scheduling in order to complete their graduate program quickly.
5. Early acceptance into a Combined Degree Program leading to a Graduate Degree assures students of automatic acceptance into full graduate status if they maintain good standing while in early-acceptance status.
6. In many cases, students will be able to complete both a Bachelor’s and a Master’s Degrees in five years of total enrollment at Mines.

Graduate programs may allow Combined Degree Program students to fulfill part of the requirements of their graduate degree by including up to six hours of specified degree credits which also were used in fulfilling the requirements of their undergraduate degree at Mines. These courses must have been passed with a “B-“ or better and meet all other University, Department, Division, and Program requirements for graduate credit, but their grades are not included in calculating the graduate GPA. Check the departmental section of the Catalog to determine which programs provide this opportunity and any program-specific requirements.

B. Admission Process

A student interested in applying into a graduate degree program as a Combined Degree Program student should first contact the department or division hosting the graduate degree program into which he/she wishes to apply. Initial inquiries may be made at any time, but initial contacts made soon after completion of the first semester, Sophomore year are recommended. Following this initial inquiry, departments/ divisions will provide initial counseling on degree application procedures, admissions standards and degree completion requirements.

Admission into a graduate degree program as a Combined Degree Program student can occur as early as the first semester, Junior year, and must be granted no later than the end of registration, last semester Senior year. Once admitted into a graduate degree program, students may enroll in 500-level courses and apply these directly to their graduate degree. To apply, students must submit the standard graduate application package for the graduate portion of their Combined Degree Program. Upon admission into a graduate degree program, students are assigned graduate advisors. Prior to registration for the next semester, students and their graduate advisors should meet and plan a strategy for completing both the undergraduate and graduate programs as efficiently as possible. Until their undergraduate degree requirements are completed, students continue to have undergraduate advisors in the home department or division of their Bachelor's Degrees.

C. Requirements

Combined Degree Program students are considered undergraduate students until such time as they complete their undergraduate degree requirements. Combined Degree Program students who are still considered undergraduates by this definition have all of the privileges and are subject to all expectations of both their undergraduate and graduate programs. These students may enroll in both undergraduate and graduate courses (see section D below), may have access to departmental assistance available through both programs, and may be eligible for undergraduate financial aid as determined by the Office of Financial Aid. Upon completion of their undergraduate degree requirements, a Combined Degree Program student is considered enrolled full-time in his/her graduate program. Once having done so, the student is no longer eligible for undergraduate financial aid, but may now be eligible for graduate financial aid. To complete their graduate degree, each Combined Degree Program student must register as a graduate student for at least one semester.

Once admitted into a graduate program, undergraduate Combined Program students must maintain good standing in the Combined Program by maintaining a minimum semester GPA of 3.0 in all courses taken. Students not meeting this requirement are deemed to be making unsatisfactory academic progress in the Combined Degree Program. Students for whom this is the case are subject to probation and, if occurring over two semesters, subject to discretionary dismissal from the graduate portion of their program as defined in the Unsatisfactory Academic Performance section of this Catalog.

Upon completion of the undergraduate degree requirements, Combined Degree Program students are subject to all requirements (e.g., course requirements, departmental approval of transfer credits, research credits, minimum GPA, etc.) appropriate to the graduate program in which they are enrolled.

D. Enrolling in Graduate Courses as a Senior in a Combined Program

As described in the Undergraduate Catalog, seniors may enroll in 500-level courses. In addition, undergraduate seniors who have been granted admission through the Combined Degree Program into thesis-based degree programs (Masters or Doctoral) may, with graduate advisor approval, register for 700-level research credits appropriate to Masters-level degree programs. With this single exception, while a Combined Degree Program student is still completing his/her undergraduate degree, all of the conditions described in the Undergraduate Catalog for undergraduate enrollment in graduate-level courses apply. 700-level research credits are always applied to a student's graduate degree program.

If an undergraduate Combined Degree Program student would like to enroll in a 500-level course and apply this course directly to his/her graduate degree, he/she must submit the 500 Level Form to the Registrar's Office. On the form, the student will select the appropriate option for the course; use as undergraduate credit or use as graduate credit.

- Students who have been accepted into a graduate level program and have submitted the "intend to enroll" information by census day of the term in which the class is taken are eligible to have the credits listed on the graduate level transcripts. In this case, the grades will impact the graduate G.P.A. and the student may take an unlimited number of credits to use towards the graduate level degree. Students must remember that all students earning a graduate degree must register at least one semester as a graduate student.
- Students who have either not been admitted into a graduate program or those who have been admitted, but have not submitted the "intend to enroll" by census day of the term in which the class is taken are <u>not</u> eligible to have the credits listed on the graduate level transcripts, even if the student does not need the credits for the undergraduate degree. In this case, the credits will be listed on the undergraduate level transcripts and the grades will impact the undergraduate G.P.A. If these credits are not used towards an undergraduate degree requirement, they may, with departmental approval, be applied to a graduate program as transfer credits. All regular regulations and limitations regarding the use of transfer credit to a graduate degree program apply to these credits.

The Registrar will forward the registration information to Financial Aid for appropriate action. Be aware that courses taken as an undergraduate student but not used toward a bachelor's degree are not eligible for undergraduate financial aid or the Colorado Opportunity Fund.

College of Engineering & Computational Sciences

The College of Engineering and Computational Sciences (CECS) comprises six academic units:

- Department of Applied Mathematics and Statistics (p. 46)
- Department of Civil and Environmental Engineering (p. 52)
- Department of Computer Science (p. 62)
- Department of Electrical Engineering (p. 68)
- Department of Mechanical Engineering (p. 76)
- Division of Engineering, Design, and Society (catalog.mines.edu/undergraduate/programs/additionalprograms/edns)

Through these departments and their programs, CECS addresses the challenges of a sustainable global society related to earth, energy and the natural and built environments by educating the next generation of leading engineering-citizen designers and scientists and expanding the frontiers of knowledge through research

If you are looking for a challenge though a world class education, if you want the skills you need to make a difference in the world, if you are interested in pursuing original research, or if you want to be part of the rich traditions of an institution that has been committed to serving the people of Colorado, the nation, and the global community since the 1870’s, we invite you to join us in the College of Engineering and Computational Sciences at the Colorado School of Mines.

Applied Mathematics & Statistics

Degrees Offered

- Master of Science (Applied Mathematics and Statistics)
- Doctor of Philosophy (Applied Mathematics and Statistics)

Program Description

The Department of Applied Mathematics and Statistics (AMS) offers two graduate degrees: A Master of Science in Applied Mathematics and Statistics and a Doctor of Philosophy in Applied Mathematics and Statistics. The master's program is designed to prepare candidates for careers in industry or government or for further study at the PhD level. The PhD program is sufficiently flexible to prepare candidates for careers in industry, government and academia. A course of study leading to the PhD degree can be designed either for students who have completed a Master of Science degree or for students with a Bachelor of Science degree.

Research within AMS is conducted in the following areas:

Computational and Applied Mathematics
Study of Wave Phenomena and Inverse Problems
Numerical Methods for PDEs
Study of Differential and Integral Equations
Computational Radiation Transport
Computational Acoustics and Electromagnetics
Multi-scale Analysis and Simulation
High Performance Scientific Computing
Dynamical Systems
Mathematical Biology

Statistics
Inverse Problems in Statistics
Multivariate Statistics
Spatial Statistics
Stochastic Models for Environmental Science
Survival Analysis
Uncertainty Quantification

Master of Science Program Requirements

The Master of Science degree (thesis option) requires 30 credit hours of acceptable coursework and research, completion of a satisfactory thesis, and successful oral defense of this thesis. At least six of the 30 credit hours must be designated for supervised research. The coursework includes the following core curriculum.

Specialty in Computational & Applied Mathematics

Required Courses

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
SYGN502	INTRODUCTION TO RESEARCH ETHICS *	1.0
MATH589	APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR **	1.0

plus two courses chosen from the following:

MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0
MATH502	REAL AND ABSTRACT ANALYSIS	3.0
MATH503	FUNCTIONAL ANALYSIS	3.0
MATH506	COMPLEX ANALYSIS II	3.0
MATH510	ORDINARY DIFFERENTIAL EQUATIONS AND DYNAMICAL SYSTEMS	3.0
MATH540	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH556	MODELING WITH SYMBOLIC SOFTWARE	3.0
MATH557	INTEGRAL EQUATIONS	3.0

*Required for students receiving federal support.

** Required only for students employed by the department as graduate teaching assistants or student instructor/lecturers.

Specialty in Statistics

Required Courses

MATH500	LINEAR VECTOR SPACES	3.0
MATH530	STATISTICAL METHODS I	3.0
MATH531	STATISTICAL METHODS II	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MATH535	MATHEMATICAL STATISTICS II	3.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS *	1.0
MATH589	APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR **	1.0

plus two courses chosen from the following:

MATH532	SPATIAL STATISTICS	3.0
MATH536	ADVANCED STATISTICAL MODELING	3.0
MATH537	MULTIVARIATE ANALYSIS	3.0
MATH538	STOCHASTIC MODELS	3.0
MATH539	SURVIVAL ANALYSIS	3.0
MATH582	STATISTICS PRACTICUM	3.0

*Required for students receiving federal support.

** Required only for students employed by the department as graduate teaching assistants or student instructor/lecturers.

For both specialties, elective courses may be selected from any other graduate courses offered by the Department of Applied Mathematics and Statistics, except for specially designated service courses. In addition, up to 6 credits of elective courses may be taken in other departments on campus.

The Master of Science degree (non-thesis option) requires 30 credit hours of coursework. The coursework includes the required core curriculum for the chosen specialty.

Combined BS/MS Program

The Department of Applied Mathematics and Statistics offers a combined Bachelor of Science/Master of Science program that enables students to work on a Bachelor of Science and a Master of Science in either specialty simultaneously. Students take 30 credit hours of coursework at the graduate level in addition to the undergraduate requirements, and work on both degrees at the same time. Students may apply for the program once they have completed five classes with a MATH prefix numbered 225 or higher.

Doctor of Philosophy Program Requirements:

The Doctor of Philosophy requires 72 credit hours beyond the bachelor's degree. At least 24 of these hours must be thesis hours. Doctoral students must pass the comprehensive examination (a qualifying examination and thesis proposal), complete a satisfactory thesis, and successfully defend their thesis. The coursework includes the following core curriculum.

Specialty in Computational & Applied Mathematics

Required Courses

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
SYGN502	INTRODUCTION TO RESEARCH ETHICS *	1.0
MATH589	APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR **	1.0

plus two courses chosen from the following;

MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0
MATH502	REAL AND ABSTRACT ANALYSIS	3.0
MATH503	FUNCTIONAL ANALYSIS	3.0
MATH506	COMPLEX ANALYSIS II	3.0
MATH510	ORDINARY DIFFERENTIAL EQUATIONS AND DYNAMICAL SYSTEMS	3.0
MATH540	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH556	MODELING WITH SYMBOLIC SOFTWARE	3.0
MATH557	INTEGRAL EQUATIONS	3.0

*Required for students receiving federal support.

** Required only for students employed by the department as graduate teaching assistants or student instructor/lecturers.

Specialty in Statistics

Required Courses

MATH500	LINEAR VECTOR SPACES	3.0
MATH530	STATISTICAL METHODS I	3.0
MATH531	STATISTICAL METHODS II	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MATH535	MATHEMATICAL STATISTICS II	3.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS *	1.0
MATH589	APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR **	1.0

plus two courses chosen from the following:

MATH532	SPATIAL STATISTICS	3.0
MATH536	ADVANCED STATISTICAL MODELING	3.0
MATH537	MULTIVARIATE ANALYSIS	3.0
MATH538	STOCHASTIC MODELS	3.0
MATH539	SURVIVAL ANALYSIS	3.0
MATH582	STATISTICS PRACTICUM	3.0

*Required for students receiving federal support.

** Required only for students employed by the department as graduate teaching assistants or student instructor/lecturers.

Further information can be found on the Web at ams.mines.edu. This website provides an overview of the programs, requirements and policies of the department.

Fields of Research

Computational and Applied Mathematics:

Study of Wave Phenomena and Inverse Problems

Numerical Methods for PDEs

Study of Differential and Integral Equations

Computational Radiation Transport

Computational Acoustics and Electromagnetics

Multi-scale Analysis and Simulation

High Performance Scientific Computing

Dynamical Systems

Mathematical Biology

Statistics:

Inverse Problems in Statistics

Multivariate Statistics

Spatial Statistics

Stochastic Models for Environmental Science

Survival Analysis

Uncertainty Quantification

Department Head

Greg Fasshauer, Professor

Professors

Bernard Bialecki

Mahadevan Ganesh

Paul A. Martin

William Navidi

Doug Nychka

Associate Professor

Soutir Bandopadhyay

Stephen Pankavich

Luis Tenorio

Assistant Professors

Cecilia Diniz Behn

Karin Leiderman

Teaching Professors

Debra Carney

G. Gustave Greivel

Mike Nicholas

Scott Strong

Rebecca Swanson

Teaching Associate Professors

Terry Bridgman

Holly Eklund

Mike Mikucki

Ashlyn Munson

Jennifer Strong

Emeriti Professors

William R. Astle

Norman Bleistein

Ardel J. Boes

Austin R. Brown

John A. DeSanto

Graeme Fairweather

Raymond R. Gutzman

Frank G. Hagin

Willy Hereman

Donald C.B. Marsh

Steven Pruess

Emeriti Associate Professors

Barbara B. Bath

Ruth Maurer

Courses

MATH500. LINEAR VECTOR SPACES. 3.0 Semester Hrs.
(I) Finite dimensional vector spaces and subspaces: dimension, dual bases, annihilators. Linear transformations, matrices, projections, change of basis, similarity. Determinants, eigenvalues, multiplicity. Jordan form. Inner products and inner product spaces with orthogonality and completeness. Prerequisite: MATH301, MATH332. 3 hours lecture; 3 semester hours.

MATH501. APPLIED ANALYSIS. 3.0 Semester Hrs.
(I) Fundamental theory and tools of applied analysis. Students in this course will be introduced to Banach, Hilbert, and Sobolev spaces; bounded and unbounded operators defined on such infinite dimensional spaces; and associated properties. These concepts will be applied to understand the properties of differential and integral operators occurring in mathematical models that govern various biological, physical and engineering processes. Prerequisites: MATH301 or equivalent. 3 hours lecture; 3 semester hours.

MATH502. REAL AND ABSTRACT ANALYSIS. 3.0 Semester Hrs.
(I) Normed space R, open and closed sets. Lebesgue measure, measurable sets and functions. Lebesgue integral and convergence theorems. Repeated integration and integration by substitution. Lp spaces, Banach and Hilbert spaces. Weak derivatives and Sobalev spaces. Weak solutions of two-point boundary value problems. Prerequisites: MATH301 or equivalent. 3 hours lecture; 3 semester hours.

MATH503. FUNCTIONAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with MACS503,
(II) Properties of metric spaces, normed spaces and Banach spaces, inner product and Hilbert spaces. Fundamental theorems for normed and Banach spaces with applications. Orthogonality and orthonormal systems on Hilbert spaces with applications to approximation theory. Compact, bounded and unbounded operators. Duality, adjoint, self-adjoint, Hilbert-adjoint operators. Spectral analysis of linear operators. Applications to differential and integral equations. Prerequisites: MATH502. 3 hours lecture; 3 semester hours.

MATH506. COMPLEX ANALYSIS II. 3.0 Semester Hrs.
(II) Analytic functions. Conformal mapping and applications. Analytic continuation. Schlicht functions. Approximation theorems in the complex domain. Taught every other year. Prerequisite: MATH454. 3 hours lecture; 3 semester hours.

MATH510. ORDINARY DIFFERENTIAL EQUATIONS AND DYNAMICAL SYSTEMS. 3.0 Semester Hrs.
Equivalent with MACS510,
(I) Topics to be covered: basic existence and uniqueness theory, systems of equations, stability, differential inequalities, Poincare-Bendixon theory, linearization. Other topics from: Hamiltonian systems, periodic and almost periodic systems, integral manifolds, Lyapunov functions, bifurcations, homoclinic points and chaos theory. Offered even years. Prerequisite: (MATH225 or MATH235) and (MATH332 or MATH342). 3 hours lecture; 3 semester hours.

MATH514. APPLIED MATHEMATICS I. 3.0 Semester Hrs.
(I) The major theme in this course is various non-numerical techniques for dealing with partial differential equations which arise in science and engineering problems. Topics include transform techniques, Green's functions and partial differential equations. Stress is on applications to boundary value problems and wave theory. Prerequisite: MATH455 or equivalent. 3 hours lecture; 3 semester hours.

MATH515. APPLIED MATHEMATICS II. 3.0 Semester Hrs.
(II) Topics include integral equations, applied complex variables, an introduction to asymptotics, linear spaces and the calculus of variations. Stress is on applications to boundary value problems and wave theory, with additional applications to engineering and physical problems. Prerequisite: MATH514. 3 hours lecture; 3 semester hours.

MATH530. STATISTICAL METHODS I. 3.0 Semester Hrs.
(I) Introduction to probability, random variables, and discrete and continuous probability models. Elementary simulation. Data summarization and analysis. Confidence intervals and hypothesis testing for means and variances. Chi square tests. Distribution-free techniques and regression analysis. Prerequisite: MATH213 or equivalent. 3 hours lecture; 3 semester hours.

MATH531. STATISTICAL METHODS II. 3.0 Semester Hrs.
Equivalent with MACS531,
(II) Continuation of MATH530. Multiple regression and trend surface analysis. Analysis of variance. Experimental design (Latin squares, factorial designs, confounding, fractional replication, etc.) Nonparametric analysis of variance. Topics selected from multivariate analysis, sequential analysis or time series analysis. Prerequisite: MATH201 or MATH530 or MATH535. 3 hours lecture; 3 semester hours.

MATH532. SPATIAL STATISTICS. 3.0 Semester Hrs.
(I) Modeling and analysis of data observed on a 2 or 3-dimensional surface. 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, spatio-temporal modeling. Course is offered every other year on even years. Prerequisites: MATH424 or MATH531. 3 hours lecture; 3 semester hours.

MATH534. MATHEMATICAL STATISTICS I. 3.0 Semester Hrs.
(I) The basics of probability, discrete and continuous probability distributions, sampling distributions, order statistics, convergence in probability and in distribution, and basic limit theorems, including the central limit theorem, are covered. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH535. MATHEMATICAL STATISTICS II. 3.0 Semester Hrs.
Equivalent with MACS535,
(II) The basics of hypothesis testing using likelihood ratios, point and interval estimation, consistency, efficiency, sufficient statistics, and some nonparametric methods are presented. Prerequisite: MATH534 or equivalent. 3 hours lecture; 3 semester hours.

MATH536. ADVANCED STATISTICAL MODELING. 3.0 Semester Hrs.
(II) Modern extensions of the standard linear model for analyzing data. Topics include generalized linear models, generalized additive models, mixed effects models, and resampling methods. Offered every two years on odd years. Prerequisite: MATH335, MATH424. 3 hours lecture; 3 semester hours.

MATH537. MULTIVARIATE ANALYSIS. 3.0 Semester Hrs.
(II) Introduction to applied multivariate representations of data for use in data analysis. Topics include introduction to multivariate distributions; methods for data reduction, such as principal components; hierarchical and model-based clustering methods; factor analysis; canonical correlation analysis; multidimensional scaling; and multivariate hypothesis testing. Prerequisites: MATH 530 and MATH 332 or MATH 500. 3 hours lecture; 3.0 semester hours.

MATH538. STOCHASTIC MODELS. 3.0 Semester Hrs.
(II) An introduction to the mathematical principles of stochastic processes. Discrete- and continuous-time Markov processes, Poisson processes, Brownian motion. Offered every two years on even years. 3 hours lecture; 3 semester hours.

MATH539. SURVIVAL ANALYSIS. 3.0 Semester Hrs.
(I) Basic theory and practice of survival analysis. Topics include survival and hazard functions, censoring and truncation, parametric and non-parametric inference, the proportional hazards model, model diagnostics. Offered on odd years. Prerequisite: MATH335, MATH535. 3 hours lecture; 3 semester hours.

MATH540. PARALLEL SCIENTIFIC COMPUTING. 3.0 Semester Hrs.
(II) This course is designed to facilitate students? learning of parallel programming techniques to efficiently simulate various complex processes modeled by mathematical equations using multiple and multi-core processors. Emphasis will be placed on the implementation of various scientific computing algorithms in FORTRAN/C/C++ using MPI and OpenMP. Prerequisite: MATH307. 3 hours lecture; 3 semester hours.

MATH542. SIMULATION. 3.0 Semester Hrs.
Equivalent with MACS542,
(I) Advanced study of simulation techniques, random number, and variate generation. Monte Carlo techniques, simulation languages, simulation experimental design, variance reduction, and other methods of increasing efficiency, practice on actual problems. Prerequisite: CSCI262 (or equivalent), MATH323 (or MATH530 or equivalent). 3 hours lecture; 3 semester hours.

MATH544. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with CSCI544,
This is an advanced computer graphics course in which students will learn a variety of mathematical and algorithmic techniques that can be used to solve fundamental problems in computer graphics. Topics include global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Students will learn about modern rendering and geometric modeling techniques by reading and discussing research papers and implementing one or more of the algorithms described in the literature.

MATH547. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.
Equivalent with CSCI547,
Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on techniques applicable to spatial data such as scalar, vector and tensor fields. Topics include volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Students will learn about modern visualization techniques by reading and discussing research papers and implementing one of the algorithms described in the literature.

MATH550. NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
Equivalent with MACS550,
(II) Numerical methods for solving partial differential equations. Explicit and implicit finite difference methods; stability, convergence, and consistency. Alternating direction implicit (ADI) methods. Weighted residual and finite element methods. Prerequisite: MATH225 or MATH235, and MATH332 or MATH342. 3 hours lecture; 3 semester hours.

MATH551. COMPUTATIONAL LINEAR ALGEBRA. 3.0 Semester Hrs.
Equivalent with MACS551,
(II) Numerical analysis of algorithms for solving linear systems of equations, least squares methods, the symmetric eigenproblem, singular value decomposition, conjugate gradient iteration. Modification of algorithms to fit the architecture. Error analysis, existing software packages. Prerequisites: MATH332, CSCI407/MATH407. 3 hours lecture; 3 semester hours.

MATH556. MODELING WITH SYMBOLIC SOFTWARE. 3.0 Semester Hrs.
(I) Case studies of various models from mathematics, the sciences and engineering through the use of the symbolic software package MATHEMATICA. Based on hands-on projects dealing with contemporary topics such as number theory, discrete mathematics, complex analysis, special functions, classical and quantum mechanics, relativity, dynamical systems, chaos and fractals, solitons, wavelets, chemical reactions, population dynamics, pollution models, electrical circuits, signal processing, optimization, control theory, and industrial mathematics. The course is designed for graduate students and scientists interested in modeling and using symbolic software as a programming language and a research tool. It is taught in a computer laboratory. Prerequisites: none. 3 hours lecture; 3 semester hours.

MATH557. INTEGRAL EQUATIONS. 3.0 Semester Hrs.
(I) 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. Offered even years. Prerequisite: MATH332 or MATH342 and MATH455. 3 hours lecture; 3 semester hours.

MATH559. ASYMPTOTICS. 3.0 Semester Hrs.
Equivalent with MATH459,
(I) Exact methods for solving mathematical problems are not always available: approximate methods must be developed. Often, problems involve small parameters, and this can be exploited so as to derive approximations: these are known as asymptotic approximations. Many techniques for constructing asymptotic approximations have been devised. The course develops such approximations for algebraic problems, the evaluation of integrals, and the solutions of differential equations. Emphasis is placed on effective methods and, where possible, rigorous analysis. Prerequisites: Calculus and ordinary differential equations. 3 hours lecture; 3 semester hours.

MATH572. MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE. 3.0 Semester Hrs.
(II) 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. Prerequisite: MATH331. 3 hours lecture; 3 semester hours.

MATH574. THEORY OF CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with CSCI574,
Students will draw upon current research results to design, implement and analyze their own computer security or other related cryptography projects. The requisite mathematical background, including relevant aspects of number theory and mathematical statistics, will be covered in lecture. Students will be expected to review current literature from prominent researchers in cryptography and to present their findings to the class. Particular focus will be given to the application of various techniques to real-life situations. The course will also cover the following aspects of cryptography: 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. Prerequisites: CSCI262 plus undergraduate-level knowledge of statistics and discrete mathematics. 3 hours lecture, 3 semester hours.

MATH582. STATISTICS PRACTICUM. 3.0 Semester Hrs.
(II) This is the capstone course in the Statistics Option. The main objective is to apply statistical knowledge and skills to a data analysis problem, which will vary by semester. Students will gain experience in problem-solving; working in a team; presentation skills (both orally and written); and thinking independently. Prerequisites: MATH 201 or 530 and MATH 424 or 531. 3 hours lecture and discussion; 3 semester hours.

MATH589. APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR. 1.0 Semester Hr.
(I) An introduction to teaching issues and techniques within the AMS department. Weekly, discussion-based seminars will cover practical issues such as lesson planning, grading, and test writing. Issues specific to the AMS core courses will be included. 1 hour lecture; 1.0 semester hour.

MATH598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MATH599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MATH610. ADVANCED TOPICS IN DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
(II) Topics from current research in ordinary and/or partial differential equations; for example, dynamical systems, advanced asymptotic analysis, nonlinear wave propagation, solitons. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH614. ADVANCED TOPICS IN APPLIED MATHEMATICS. 3.0 Semester Hrs.
(I) Topics from current literature in applied mathematics; for example, wavelets and their applications, calculus of variations, advanced applied functional analysis, control theory. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH616. INTRODUCTION TO MULTI-DIMENSIONAL SEISMIC INVERSION. 3.0 Semester Hrs.
(II) Introduction to high frequency inversion techniques. Emphasis on the application of this theory to produce a reflector map of the earth?s interior and estimates of changes in earth parameters across those reflectors from data gathered in response to sources at the surface or in the interior of the earth. Extensions to elastic media are discussed, as well. Includes high frequency modeling of the propagation of acoustic and elastic waves. Prerequisites: partial differential equations, wave equation in the time or frequency domain, complex function theory, contour integration. Some knowledge of wave propagation: reflection, refraction, diffraction. 3 hours lecture; 3 semester hours.

MATH650. ADVANCED TOPICS IN NUMERICAL ANALYSIS. 3.0 Semester Hrs.
(II) Topics from the current literature in numerical analysis and/or computational mathematics; for example, advanced finite element method, sparse matrix algorithms, applications of approximation theory, software for initial value ODE?s, numerical methods for integral equations. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH691. GRADUATE SEMINAR. 1.0 Semester Hr.
(I) Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

MATH692. GRADUATE SEMINAR. 1.0 Semester Hr.
Equivalent with CSCI692,MACS692,
(II) Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

MATH693. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.
(I, II) Students will probe a range of current methodologies and issues in seismic data processing, with emphasis on under lying assumptions, implications of these assumptions, and implications that would follow from use of alternative assumptions. Such analysis should provide seed topics for ongoing and subsequent research. Topic areas include: Statistics estimation and compensation, deconvolution, multiple suppression, suppression of other noises, wavelet estimation, imaging and inversion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Prerequisite: none. 1 hour seminar; 1 semester hour.

MATH698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MATH699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MATH707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Civil and Environmental Engineering

Degrees Offered

- Master of Science (Civil and Environmental Engineering)
- Doctor of Philosophy (Civil and Environmental Engineering)
- Master of Science (Environmental Engineering Science)
- Doctor of Philosophy (Environmental Engineering Science)

Program Description

The Civil and Environmental Engineering Department offers two M.S. and Ph.D. graduate degrees - Civil & Environmental Engineering(CEE) and Environmental Engineering Science (EES). The Civil and Environmental Engineering (CEE) degree is designed for students who wish to earn a degree to continue the path towards professional engineering registration. Students entering this degree program should have a B.S. degree in engineering, or will generally need to take engineering prerequisite courses. Within the CEE degree, students complete specified requirements in one of three different emphasis areas: Environmental and Water Engineering, Geotechnical Engineering (GT), and Structural Engineering (SE).

The Environmental Engineering Science (EES) degree does not require engineering credentials and has a flexible curriculum that enables students with a baccalaureate degree in biology, chemistry, math, physics, geology, engineering, and other technical fields, to tailor a course-work program that best fits their career goals.

The specific requirements for the EES & CEE degrees, as well as for the four emphasis areas within the CEE degree, are described in detail under the Major tab.

The M.S. and Ph.D. degrees in Environmental Engineering Science (EES) has been admitted to the Western Regional Graduate Program (WRGP/WICHE), a recognition that designates this curriculum as unique within the Western United States. An important benefit of this designation is that students who are residents from Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming are given the tuition status of Colorado residents.

To achieve the Master of Science (M.S.) degree, students may elect the Non-Thesis option, based exclusively upon coursework and project activities, or the Thesis option, which requires coursework and rigorous research conducted under the guidance of a faculty advisor and M.S. thesis committee, that is described in a final written thesis that is defended in an oral presentation.

The Doctor of Philosophy (Ph.D.) degree requires students to complete a combination of coursework and original research, under the guidance of a faculty advisor and doctoral committee, that culminates in a significant scholarly contribution (e.g., in the form of published journal articles) to a specialized field in Civil and Environmental Engineering or Environmental Engineering Science. The written dissertation must be defended in an public oral presentation before the advisor and dissertation committee. The Ph.D. program may build upon one of the CEE or EES M.S. programs or a comparable M.S. program at another university. Full-time PhD enrollment is expected and leads to the greatest success, although part-time enrollment may be allowed under special circumstances.

Faculty Expertise and General Emphasis Areas:

Civil and Environmental Engineering faculty have expertise in environmental science and engineering, geotechnical engineering, hydrology, water-resources engineering, structural engineering, and underground construction and tunneling. These areas also serve as topic areas for coursework and for M.S. thesis or PhD dissertation research, and are the basis for degree requirements.

Environmental Engineering and Science: Is the application of environmental processes in natural and engineered systems. CEE faculty have expertise in water resource engineering, biosystems engineering, environmental chemistry, environmental microbiology, microbial genomics, wastewater treatment, water treatment, bioremediation, mining treatment processes and systems, remediation processes, biogeochemical reactions in soils, geobiology, membrane processes, humanitarian engineering, social aspects of engineering, and energy recovery from fluids.

Geotechnical Engineering: Geotechnical Engineering is concerned with the engineering properties and behavior of natural and engineered geomaterials (soils and rocks), as well as the design and construction of foundations, earth dams and levees, retaining walls, embankments, underground structures and tunnels. Almost all constructed projects require input from geotechnical engineers as most structures are built on, in or of geomaterials. Additionally, mitigation of the impact of natural hazards such as earthquakes and landslides, sustainable use of energy and resources, and reduction of the environmental impacts of human activities require geotechnical engineers who have in-depth understanding of how geomaterials respond to loads, and environmental changes. Students who pursue this discipline complete the requirements of the Geotechnical Engineering emphasis area within the Civil & Environmental Engineering degree program.

Structural Engineering: Is a multidisciplinary subject spanning the disciplines of civil engineering, aerospace engineering, mechanical engineering, and marine engineering. In all these disciplines, structural engineers use engineered materials and conduct analyses using general principles of structural mechanics, to design structures for civil systems. Designed systems may include bridges, dams, buildings, tunnels, sustainable infrastructure, highways, biomechanical apparatus, sustainable civil engineering materials and numerous other structures and devices. Students who pursue this discipline complete the requirements of the Structural Engineering (SE) emphasis area within the Civil & Environmental Engineering Degree program.

Hydrology and Water Resources Engineering: Students interested in this area have two options. Students interested in natural-systems hydrology, ground-water resources, contaminant transport, and hydrochemical processes often choose to earn a degree in “Hydrology” in the interdisciplinary Hydrologic Science and Engineering (HSE) program (see HSE section of this graduate catalog). Students interested in engineered water systems or water-resources engineering, such as water infrastructure, water reclamation and reuse, ground-water remediation, contaminated water bodies, urban hydrology, water-resources management, and fluid mechanics typically choose the CEE degree - Environmental and Water Engineering Emphasis area. Students who are interested in the chemical, biological and fundamental water science that serves as the foundation for hydrology and water resources engineering may also elect the EES degree.

Underground Construction & Tunneling (UC&T): UC&T involves the planning, design, construction and rehabilitation of underground space (caverns, shafts, tunnels) in soil and rock. The main domains for UC&T include civil infrastructure, e.g., water and wastewater conveyance and storage, construction, transportation, and utilities, as well as underground facilities for civil, commercial and military use. UC&T is an interdisciplinary field involving civil, geological and mining engineering programs. Students interested in interdisciplinary studies including soil & rock mechanics, engineering geology and excavation methods can pursue the M.S. and/or Ph.D. in UC&T (see UC&T section of this graduate catalog, and the website uct.mines.edu). CEE students may also take elective courses and pursue research in UC&T yet emphasize geotechnical and/or structural engineering within the CEE graduate degrees.

Combined Degree Program Option

CSM undergraduate students have the opportunity to begin work on a M.S. degree in Civil & Environmental Engineering or Environmental Engineering Science while completing their Bachelor's degree. For more information please contact the CEE Office or visit cee.mines.edu

Program Requirements

General Degree Requirements for CEE and EES degrees:

M.S. Non-Thesis Option: 30 total credit hours, consisting of coursework (27 h) and either a three credit hour research based Independent Study (CEEN599) or a designated design course (3 h) and seminar.

M.S. Thesis Option: 30 total credit hours, consisting of coursework (24 h), seminar, and research (6 h). Students must also write and orally defend a research thesis.

Ph.D.: 72 total credit hours, consisting coursework (at least 24 h), seminar, and research (at least 24 h). Students must also successfully complete written and oral qualifying examinations, prepare and present a dissertation proposal, and write and defend a doctoral dissertation. Ph.D. students are also expected to submit the dissertation work for publication in scholarly journals.

Prerequisites for CEE and EES degrees:

- Baccalaureate degree: required, preferably in a science or engineering discipline
- College calculus I & II: two semesters required
- College physics: one semester required, two semesters highly recommended
- College chemistry I & II: two semesters required
- College probability & statistics: one semester required
- All CEE degree emphasis areas require completion of the general science pre-requisites listed above, and also requires statics, dynamics, and differential equations. In addition, the CEE degree emphasis areas may require specific additional pre-requisites as listed below.

Required Curriculum for Environmental Engineering Science (EES) Degree:

The EES curriculum consists of common core and elective courses that may be focused toward specialized areas of emphasis. The common core includes:

- CEEN550 CEEN550: Principles of Environmental Chemistry
- CEEN592: Environmental Law or approved policy / law course
- CEEN580: Environmental Fate and Transport
- CEEN560 Molecular Microbial Ecology or CEEN562 Applied Geomicrobiology or CEEN566 Microbial Processes, Analysis and Modeling
- 3-credit Independent Study (CEEN599) or a 3 credit hour design course

Students earning an EES degree work with their academic advisor to establish plans of study that best fit their individual interests and goals. Each student will develop and submit a plan of study during the first semester of enrollment; this plan must be submitted with the admission to candidacy form. Electives may be chosen freely from courses offered at CSM and other local universities. Please visit the CEE website for a complete outline of curriculum requirements and options (www.cee.mines.edu).

Required Curriculum for Civil and Environmental Engineering (CEE) Degree:

The CEE curriculum contains emphasis areas: Environmental and Water Engineering, Geotechnical Engineering, and Structural Engineering. CEE students must complete the requirements for at least one emphasis area.

Core Courses: Each emphasis area has required core courses that apply to MS and PhD degrees. These core courses are listed below.

Electives: CEE degree emphasis areas require additional engineering-course electives: 12 credits for M.S. thesis option, 15 credits for M.S. non-thesis option and 18 credits for Ph.D. A variety of engineering courses may be taken for electives in the CEE emphasis areas, including additional CEEN courses, as well as courses from other departments on campus. The student's advisor and committee must approve elective courses.

Non thesis students must take take at least 21 elective credits within the CEEN prefix.

CEE Degree Emphasis Areas

GEOTECHNICAL ENGINEERING

Additional Prerequisites Courses: soil mechanics, structural theory/ structural analysis

Geotechnical Core Courses: Students are required to successfully complete four courses (12 credit hours) from the following core course list plus CEEN590 Civil Engineering seminar.

CEEN510	ADVANCED SOIL MECHANICS	3.0
CEEN511	UNSATURATED SOIL MECHANICS	3.0
CEEN512	SOIL BEHAVIOR	3.0
CEEN514	SOIL DYNAMICS	3.0
CEEN515	HILLSLOPE HYDROLOGY AND STABILITY	3.0
CEEN520	EARTH RETAINING STRUCTURES / SUPPORT OF EXCAVATIONS (*)	3.0
CEEN523	UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND (*)	4.0

* Design Course

ENVIRONMENTAL AND WATER ENGINEERING

Additional Prerequisites Courses: fluid mechanics.

Environmental & Water Engineering Core Courses: Students are required to successfully complete one course as specified in each of the following areas plus CEEN596 Environmental Seminar:

Chemistry: CEEN550 Principles of Env Chemistry

Physical Transport: CEEN580 Env Pollution

Bio Processes: CEEN560 Molecular Microbial Ecology
or CEEN562 Geomicrobial Systems or CEEN566 Microbial Processes, Analysis and Modeling*

Systems Design: CEEN570 Treatment of Waters & Waste *
or CEEN471 Water & Wastewater Treatment Systems*

*Design Course

STRUCTURAL ENGINEERING

Additional Prerequisites Courses: soil mechanics, structural theory / structural analysis.

Structural Engineering Core Courses: Three courses from the following, 9 credits total including at least 3 credits of design course, plus CEEN590 Civil Engineering seminar.

CEEN506	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN530	ADVANCED STRUCTURAL ANALYSIS	3.0
CEEN531	STRUCTURAL DYNAMICS	3.0
CEEN540	ADVANCED DESIGN OF STEEL STRUCTURES (*)	3.0
CEEN541	DESIGN OF REINFORCED CONCRETE STRUCTURES II (*)	3.0
CEEN542	TIMBER AND MASONRY DESIGN (*)	3.0
CEEN543	CONCRETE BRIDGE DESIGN BASED ON THE AASHTO LRFD SPECIFICATIONS (*)	3.0

* Design Course

Department Head

Terri Hogue

Professors

Tzahi Cath

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Joseph Crocker

Kristoph Kinzli

Susan Reynolds

Teaching Associate Professors

Andres Guerra

Hongyan Liu

Alexandra Wayllace

Teaching Assistant Professor

Jeffery Holley

Adjunct Faculty

Sidney Innerebner

Paul B. Queneau

Tanja Rauch

Patrick Ryan

Courses

CEEN501. LIFE CYCLE ASSESSMENT. 3.0 Semester Hrs.
(II) 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. 3 hours lecture; 3 semester hours.

CEEN505. NUMERICAL METHODS FOR ENGINEERS. 3.0 Semester Hrs.

Equivalent with EGGN560,

(S) Introduction to the use of numerical methods in the solution of commonly encountered problems of engineering analysis. Structural/solid analysis of elastic materials (linear simultaneous equations); vibrations (roots of nonlinear equations, initial value problems); natural frequency and beam buckling (eigenvalue problems); interpretation of experimental data (curve fitting and differentiation); summation of pressure distributions (integration); beam deflections (boundary value problems). All course participants will receive source code of all the numerical methods programs published in the course textbook which is coauthored by the instructor. Prerequisite: MATH225. 3 hours lecture; 3 semester hours.

CEEN506. FINITE ELEMENT METHODS FOR ENGINEERS. 3.0 Semester Hrs.

Equivalent with EGGN542,

(II) 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. Students get a copy of all the source code published in the course textbook. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN510. ADVANCED SOIL MECHANICS. 3.0 Semester Hrs.

Equivalent with EGGN548,

Advanced soil mechanics theories and concepts as applied to analysis and design in geotechnical engineering. Topics covered will include seepage, consolidation, shear strength, failure criteria and constitutive models for soil. The course will have an emphasis on numerical solution techniques to geotechnical problems by finite elements and finite differences. Prerequisites: A first course in soil mechanics. 3 Lecture Hours, 3 semester hours. Fall even years.

CEEN511. UNSATURATED SOIL MECHANICS. 3.0 Semester Hrs.

Equivalent with EGES533,EGGN533,

The focus of this course is on soil mechanics for unsaturated soils. It provides an introduction to thermodynamic potentials in partially saturated soils, chemical potentials of adsorbed water in partially saturated soils, phase properties and relations, stress state variables, measurements of soil water suction, unsaturated flow laws, measurement of unsaturated permeability, volume change theory, effective stress principle, and measurement of volume changes in partially saturated soils. The course is designed for seniors and graduate students in various branches of engineering and geology that are concerned with unsaturated soil?s hydrologic and mechanics behavior. When this course is cross-listed and concurrent with CEEN412, students that enroll in CEEN511 will complete additional and/or more complex assignments. Prerequisites: CEEN312. 3 hours lecture; 3 semester hours. Spring even years.

CEEN512. SOIL BEHAVIOR. 3.0 Semester Hrs.

Equivalent with EGES534,EGGN534,

(I) The focus of this course is on interrelationships among the composition, fabric, and geotechnical and hydrologic properties of soils that consist partly or wholly of clay. The course will be divided into two parts. The first part provides an introduction to the composition and fabric of natural soils, their surface and pore-fluid chemistry, and the physico-chemical factors that govern soil behavior. The second part examines what is known about how these fundamental characteristics and factors affect geotechnical properties, including the hydrologic properties that govern the conduction of pore fluid and pore fluid constituents, and the geomechanical properties that govern volume change, shear deformation, and shear strength. The course is designed for graduate students in various branches of engineering and geology that are concerned with the engineering and hydrologic behavior of earth systems, including geotechnical engineering, geological engineering, environmental engineering, mining engineering, and petroleum engineering. When this course is cross-listed and concurrent with CEEN411, students that enroll in CEEN512 will complete additional and/or more complex assignments. Prerequisites: CEEN361 Soil Mechanics. 3 hours lecture; 3 semester hours.

CEEN513. ADVANCED GEOMATERIAL MECHANICS. 4.0 Semester Hrs.

(I) This course deals with the classification and engineering behavior of soil and rock materials as well as materials used in underground construction such as structural steel, aggregates, cement, timber, concrete, shotcrete, accelerators and ground conditioning agents. This course presents an advanced treatment of soil and rock mechanics with focus on the following topics: Index and classification properties of soils, Physical properties and classification of intact rock and rock masses, Fluid flow in soils and rocks, Compressibility of soils and rocks, Failure theories and strength testing of soils and rocks, Shear strength of soils and rocks, Stresses and deformations around underground openings, Laboratory and field methods for evaluation of soil and rock properties, and Analytical and empirical approaches for the design and construction of structures in soil and rock materials. Prerequisites: Undergraduate degree in a pertinent discipline of engineering or equivalent and undergraduate level knowledge of material behavior. Co-requisites: GEGN561. 4 hours lecture; 4 semester hours.

CEEN514. SOIL DYNAMICS. 3.0 Semester Hrs.

Equivalent with EGGN531,

(II) Dynamic phenomena in geotechnical engineering, e.g., earthquakes, pile and foundation vibrations, traffic, construction vibrations; behavior of soils under dynamic loading, e.g., small, medium and large strain behavior, soil liquefaction; wave propagation through soil and rock; laboratory and field techniques to assess dynamic soil properties; analysis and design of shallow and deep foundations subjected to dynamic loading; analysis of construction vibrations. Prerequisites: CEEN312, MEGN315, CEEN415. 3 hours lecture; 3 semester hours.

CEEN515. HILLSLOPE HYDROLOGY AND STABILITY. 3.0 Semester Hrs.

Equivalent with EGGN536,

(I) Introduction of shallow landslide occurrence and socio-economic dynamics. Roles of unsaturated flow and stress in shallow landslides. Slope stability analysis based on unsaturated effective stress conceptualization. Computer modeling of unsaturated flow and stress distributions in hillslope. Prediction of precipitation induced shallow landslides. Prerequisite: CEEN312. 3 hours lecture; 3 semester hours.

CEEN520. EARTH RETAINING STRUCTURES / SUPPORT OF EXCAVATIONS. 3.0 Semester Hrs.
(II) Analysis, design, construction and monitoring of earth retaining structures and support of excavations used for permanent and temporary support of transportation facilities, bridges, underground structures and tunnels, shafts, waterfront structures, earth slopes and embankments. Includes gravity, semi-gravity, cantilevered, anchored, geosynthetic and ground improvement walls. Addresses fundamental geomechanics required for analysis and design, ASD (allowable stress design) and LRFD (load resistance factor design) design techniques, and construction techniques. Prerequisites: Undergraduate Introduction to Geotechnical Engineering course (i.e., similar to CEEN312). 3 hours lecture and discussion; 3 semester hours.

CEEN523. UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND. 4.0 Semester Hrs.
(II) Design and construction of water, wastewater, transportation and utility tunnels, underground space and shafts/excavations in soft ground conditions (soil and weak rock). Addresses geotechnical site characterization, selection of design parameters, stability and deformation analysis of the ground and overlying structures, and construction methods. Includes design of temporary and permanent structural ground support according to ASD (allowable stress design) and LRFD (load resistance factor design) approaches, and design of ground improvement schemes and instrumentation/monitoring approaches to mitigate risk. This course requires post-graduate level knowledge of soil mechanics, fundamental understanding of engineering geology, and an undergraduate level knowledge of structural analysis and design. Prerequisites: CEEN513 and GEGN468. Co-requisites: GEGN562. 4 hours lecture; 4 semester hours.

CEEN530. ADVANCED STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with EGGN541,
(I) 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. Prerequisite: CEEN314. 3 hour lectures, 3 semester hours.

CEEN531. STRUCTURAL DYNAMICS. 3.0 Semester Hrs.
Equivalent with EGGN557,
An introduction to the dynamics and earthquake engineering of structures is provided. Subjects include the analysis of linear and nonlinear single-degree and multi-degree of freedom structural dynamics. The link between structural dynamics and code-based analysis and designs of structures under earthquake loads is presented. he focus applicaitons of the course include single story and multi-story buildings, and other types of sructures that under major earthquake may respond in the inelastic range. Prerequisites: CEEN314 Structural Theory. 3 semester hours.

CEEN533. MATRIX STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with CEEN433,
(II) 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 CEEN433, students that enroll in CEEN533 will complete additional and/or more complex assignments. Prerequisites: CEEN314 Elementary Structural Theory. 3 lecture hours, 3 semester hours.

CEEN540. ADVANCED DESIGN OF STEEL STRUCTURES. 3.0 Semester Hrs.
Equivalent with EGGN549,
The course extends the coverage of steel design to include the topics: slender columns, beam-columns, frame behavior, bracing systems and connections, stability, moment resisting connections, composite design, bolted and welded connections under eccentric loads and tension, and semi-rigid connections. Prerequisite: CEEN443 or equivalent. 3 hours lecture; 3 semester hours. Spring even years.

CEEN541. DESIGN OF REINFORCED CONCRETE STRUCTURES II. 3.0 Semester Hrs.
Equivalent with EGGN556,
Advanced problems in the analysis and design of concrete structures, design of slender columns; biaxial bending; two-way slabs; strut and tie models; lateral and vertical load analysis of multistory buildings; introduction to design for seismic forces; use of structural computer programs. Prerequisite: CEEN445. 3 hour lectures, 3 semester hours. Delivered in the spring of even numbered years.

CEEN542. TIMBER AND MASONRY DESIGN. 3.0 Semester Hrs.
Equivalent with EGGN547,
The course develops the theory and design methods required for the use of timber and masonry as structural materials. The design of walls, beams, columns, beam-columns, shear walls, and structural systems are covered for each material. Gravity, wind, snow, and seismic loads are calculated and utilized for design. Connection design and advanced seismic analysis principles are introduced. Prerequisite: CEEN314 or equivalent. 3 hours lecture; 3 semester hours. Spring odd years.

CEEN543. CONCRETE BRIDGE DESIGN BASED ON THE AASHTO LRFD SPECIFICATIONS. 3.0 Semester Hrs.
Equivalent with EGGN558,
This course presents the fundamentals of concrete bridge analysis and design including conceptual design, superstructure analysis, AASHTO-LRFD bridge specifications, flat slab bridge design, and pre-stressed concrete bridge design. The course is presented through the complete design of the superstructure of an example bridges. At the conclusion of the course, students will be able to analyze and design simple, but complete concrete bridge superstructures. Prerequisites: CEEN445, Design of Reinforced Concrete Structure. 3 hours lecture; 3 semester hours.

CEEN544. STRUCTURAL PRESERVATION OF EXISTING AND HISTORIC BUILDINGS. 3.0 Semester Hrs.
(I, II) A broad discussion of historic structural systems in the United States, including stone and brick masonry, terra cotta, timber, cast and wrought iron, early steel, and early concrete. Combines research of historic manuals with contemporary analysis. Introduces nondestructive tests for historic structures. Enables prediction of deterioration mechanisms and structural deficiencies. Synthesizes structural retrofit solutions with preservation philosophy and current building codes. Emphasizes the engineer?s role in stewardship of historic buildings. Prerequisites: CEEN443 and CEEN445. 3 hours lecture and discussion; 3 semester hours.

CEEN545. STEEL BRIDGE DESIGN. 3.0 Semester Hrs.
(I, II, S) Students are introduced to, and will develop an understanding of, the theory, analysis, and AASHTO code requirements for the design of steel bridge superstructures. The students will become familiar with bridge types, required loadings, composite action, plate girder design, and the Load and Resistance Factor Design method. The students will recognize the design requirements for a steel bridge superstructure and perform calculations for member loads and the loadings it transfers to the substructure. Prerequisites: CEEN443. 3 hours lecture; 3 semester hours.

CEEN546. STATISTICAL METHODS FOR RELIABILITY AND ENGINEERING DESIGN. 3.0 Semester Hrs.

(I, II, S) The course will introduce methods and principles that help quantifying the effects of uncertainty in the performance prediction of civil infrastructure systems. Students will learn to apply quantitative risk analysis and modeling approaches relevant to design problems in civil engineering. The course emphasizes that the systematic treatment of uncertainty and risk quantification are essential for adequate engineering planning, design, and operation of systems. The statistical approaches fundamental to engineering design and theory of reliability in structural and underground infrastructure design will be the focus of the course and examples. 3 hours lecture; 3 semester hours.

CEEN550. PRINCIPLES OF ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.

Equivalent with ESGN500,

This course provides an introduction to chemical equilibria in natural waters and engineered systems. Topics covered include chemical thermodynamics and kinetics, acid/base chemistry, open and closed carbonate systems, precipitation reactions, coordination chemistry, adsorption and redox reactions. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN551. ENVIRONMENTAL ORGANIC CHEMISTRY. 3.0 Semester Hrs.

Equivalent with ESGN555,

A study of the chemical and physical interactions which determine the fate, transport and interactions of organic chemicals in aquatic systems, with emphasis on chemical transformations of anthropogenic organic contaminants. Prerequisites: A course in organic chemistry and CHGN503, Advanced Physical Chemistry or its equivalent. Offered in alternate years. 3 hours lecture; 3 semester hours.

CEEN552. CHEMISTRY OF THE SOIL / WATER INTERFACE. 3.0 Semester Hrs.

Equivalent with ESGN525,

The fate of many elements in the soil/water environment is regulated by sorption reactions. The content of this course focuses on the physical chemistry of reactions occurring at the soil-particle/water interface. The emphasis is on the use of surface complexation models to interpret solute sorption at the particle/water interface. Prerequisites: CEEN550. 3 hours lecture; 3 semester hours.

CEEN553. ENVIRONMENTAL RADIOCHEMISTRY. 3.0 Semester Hrs.

Equivalent with ESGN510,

This course covers the phenomena of radioactivity (e.g., modes of decay, methods of detection and biological effects) and the use of naturally occurring and artificial radionuclides as tracers for environmental processes. Discussions of tracer applications will range from oceanic trace element scavenging to contaminant transport through groundwater aquifers. Prerequisites: CEEN 550. 3 hours lecture; 3 semester hours.

CEEN555. LIMNOLOGY. 3.0 Semester Hrs.

Equivalent with ESGN513,

This course covers the natural chemistry, physics, and biology of lakes as well as some basic principles concerning contamination of such water bodies. Topics include heat budgets, water circulation and dispersal, sedimentation processes, organic compounds and their transformations, radionuclide limnochronology, redox reactions, metals and other major ions, the carbon dioxide system, oxygen, nutrients; planktonic, benthic and other communities, light in water and lake modeling. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN556. MINING AND THE ENVIRONMENT. 3.0 Semester Hrs.

Equivalent with ESGN556,

The course will cover many of the environmental problems and solutions associated with each aspect of mining and ore dressing processes. Mining is a complicated process that differs according to the type of mineral sought. The mining process can be divided into four categories: Site Development; Extraction; Processing; Site Closure. Procedures for hard rock metals mining; coal mining; underground and surface mining; and in situ mining will be covered in relation to environmental impacts. Beneficiation, or purification of metals will be discussed, with cyanide and gold topics emphasized. Site closure will be focused on; stabilization of slopes; process area cleanup; and protection of surface and ground water. After discussions of the mining and beneficiation processes themselves, we will look at conventional and innovative measures to mitigate or reduce environmental impact.

CEEN558. ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES. 3.0 Semester Hrs.

Equivalent with ESGN511,

The stewardship of nuclear resources spans the entire nuclear fuel cycle, which includes mining and milling through chemical processing on the front end of the materials life cycle. On the back end, stewardship continues from materials removal from the power plant during re-fueling or facility decommissioning, through storage, recycling and disposal, as well as the management of activated or contaminated materials generated during facility decommissioning. Each stage in the fuel cycle has a different risk of public exposure through different pathways and the presence of different isotopes. These risks are an integral part in considering the long-term efficacy of nuclear as an energy alternative. Furthermore, nuclear energy has long been vilified in public opinion forums via emotional responses. Stewardship extends beyond quantification of risks to the incorporation and communication of these risks and the associated facts regarding nuclear power to the public at large. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours.

CEEN560. MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs.

Equivalent with ESGN586,

This course explores the diversity of microbiota in a few of the countless environments of our planet. Topics include microbial ecology (from a molecular perspective), microbial metabolism, pathogens, extreme environments, engineered systems, oxidation / reduction of metals, bioremediation of both organics and inorganics, microbial diversity, phylogenetics, analytical tools and bioinformatics. The course has an integrated laboratory component for applied molecular microbial ecology to learn microscopy, DNA extraction, PCR, gel electrophoresis, cloning, sequencing, data analysis and bioinformatic applications. Prerequisite: College Biology and/or CHGC562, CHGC563 or equivalent and enrollment in the ESE graduate program. 3 hours lecture, some field trips; 3 semester hours.

CEEN562. ENVIRONMENTAL GEOMICROBIOLOGY. 3.0 Semester Hrs.

Equivalent with BELS596,ESGN596,

(II) This course explores the functional activities and biological significance of microorganisms in geological and engineered systems with a focus on implications to water resources. Topics include: microorganisms as geochemical agents of change, mechanisms and thermodynamics of microbial respiration, applications of analytical, material science and molecular biology tools to the field, and the impact of microbes on the fate and transport of problematic water pollutants. Emphasis will be placed on critical analysis and communication of peer-reviewed literature on these topics. 3 hours lecture and discussion; 3 semester hours.

CEEN564. ENVIRONMENTAL TOXICOLOGY. 3.0 Semester Hrs.

Equivalent with BELS545,ESGN545,

This course provides an introduction to general concepts of ecology, biochemistry, and toxicology. The introductory material will provide a foundation for understanding why, and to what extent, a variety of products and by-products of advanced industrialized societies are toxic. Classes of substances to be examined include metals, coal, petroleum products, organic compounds, pesticides, radioactive materials, and others. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN565. AQUATIC TOXICOLOGY. 3.0 Semester Hrs.

Equivalent with BELS544,ESGN544,

This course provides an introduction to assessment of the effects of toxic substances on aquatic organisms, communities, and ecosystems. Topics include general toxicological principles, water quality standards, sediment quality guidelines, quantitative structure-activity relationships, single species and community-level toxicity measures, regulatory issues, and career opportunities. The course includes hands-on experience with toxicity testing and subsequent data reduction. Prerequisite: none. 2.5 hours lecture; 1 hour laboratory; 3 semester hours.

CEEN566. MICROBIAL PROCESSES, ANALYSIS AND MODELING. 3.0 Semester Hrs.

Equivalent with BELS541,ESGN541,

Microorganisms facilitate the transformation of many organic and inorganic constituents. Tools for the quantitative analysis of microbial processes in natural and engineered systems will be presented. Stoichiometries, energetics, mass balances and kinetic descriptions of relevant microbial processes allow the development of models for specific microbial systems. Simple analytical models and complex models that require computational solutions will be presented. Systems analyzed include suspended growth and attached growth reactors for municipal and industrial wastewater treatment as well as in-stu bioremediation and bioenergy systems. 3 hours lecture; 3 semester hours.

CEEN570. WATER AND WASTEWATER TREATMENT. 3.0 Semester Hrs.

Equivalent with ESGN504,

Unit operations and processes in environmental engineering are discussed in this course, including physical, chemical, and biological treatment processes for water and wastewater. Treatment objectives, process theory, and practice are considered in detail. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN571. ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE. 3.0 Semester Hrs.

Equivalent with ESGN506,

This course presents issues relating to theory, design, and operation of advanced water and wastewater treatment unit processes and water reuse systems. Topics include granular activated carbon (GAC), advanced oxidation processes (O3/H2O2), UV disinfection, pressure-driven, current-driven, and osmotic-driven membranes (MF, UF, NF, RO, electrodialysis, and forward osmosis), and natural systems such as riverbank filtration (RBF) and soil-aquifer treatment (SAT). The course is augmented by CEEN571L offering hands-on experience using bench- and pilot-scale unit operations. Prerequisite: CEEN470 or CEEN471 or CEEN570 or CEEN572. 3 hours lecture; 3 semester hours.

CEEN571L. ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE - LABORATORY. 1.0 Semester Hr.

Equivalent with ESGN506L,

This course provides hands-on experience using bench- and pilotscale unit operations and computer exercises using state-ofthe- art software packages to design advanced water treatment unit processes. Topics include adsorption processes onto powdered and granular activated carbon, low-pressure membrane processes (microfiltration, ultrafiltration), and highpressure and current-driven membrane processes (nanofiltration, reverse osmosis, and electrodialysis). The course is a highly recommended component of CEEN571 and meets 5 - 6 times during the semester to support the work in CEEN571. Co- or Pre-requisite: CEEN571. 1 semester hour.

CEEN572. ENVIRONMENTAL ENGINEERING PILOT PLANT LABORATORY. 4.0 Semester Hrs.

Equivalent with ESGN530,

This course provides an introduction to bench and pilot-scale experimental methods used in environmental engineering. Unit operations associated with water and wastewater treatment for real-world treatment problems are emphasized, including multi-media filtration, oxidation processes, membrane treatment, and disinfection processes. Investigations typically include: process assessment, design and completion of bench- and pilot-scale experiments, establishment of analytical methods for process control, data assessment, upscaling and cost estimation, and project report writing. Projects are conducted both at CSM and at the City of Golden Water Treatment Pilot Plant Laboratory. Prerequisites: CEEN550 and CEEN570. 6 hours laboratory; 4 semester hours.

CEEN573. RECLAMATION OF DISTURBED LANDS. 3.0 Semester Hrs.

Equivalent with ESGN552,

Basic principles and practices in reclaiming disturbed lands are considered in this course, which includes an overview of present legal requirements for reclamation and basic elements of the reclamation planning process. Reclamation methods, including recontouring, erosion control, soil preparation, plant establishment, seed mixtures, nursery stock, and wildlife habitat rehabilitation, will be examined. Practitioners in the field will discuss their experiences. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN574. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.

Equivalent with ESGN562,

This course will examine, using case studies, ways in which 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: CEEN550. 3 hours lecture; 3 semester hours.

CEEN575. HAZARDOUS WASTE SITE REMEDIATION. 3.0 Semester Hrs.

Equivalent with ESGN575,

This course covers remediation technologies for hazardous waste contaminated sites, including site characteristics and conceptual model development, remedial action screening processes, and technology principles and conceptual design. Institutional control, source isolation and containment, subsurface manipulation, and in situ and ex situ treatment processes will be covered, including unit operations, coupled processes, and complete systems. Case studies will be used and computerized tools for process selection and design will be employed. Prerequisite: CEEN550 and CEEN580. 3 hours lecture; 3 semester hours.

CEEN575L. HAZARDOUS WASTE SITE REMEDIATION: TREATABILITY TESTING. 1.0 Semester Hr.

Equivalent with ESGN575L,

This laboratory module is designed to provide hands-on experience with treatability testing to aid selection and design of remediation technologies for a contaminated site. The course will be comprised of laboratory exercises in Coolbaugh Hall and possibly some field site work near CSM. Pre-requisite: CEEN575. 2 hours laboratory; 1 semester hour.

CEEN576. POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE. 3.0 Semester Hrs.

Equivalent with ESGN563,

The objective of this course is to introduce the principles of pollution prevention, environmentally benign products and processes, and manufacturing systems. The course provides a thorough foundation in pollution prevention concepts and methods. Engineers and scientists are given the tools to incorporate environmental consequences into decision-making. Sources of pollution and its consequences are detailed. Focus includes sources and minimization of industrial pollution; methodology for life-cycle assessments and developing successful pollution prevention plans; technological means for minimizing the use of water, energy, and reagents in manufacturing; and tools for achieving a sustainable society. Materials selection, process and product design, and packaging are also addressed. 3 hours lecture; 3 semester hours.

CEEN580. CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT. 3.0 Semester Hrs.

Equivalent with ESGN503,

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: none. 3 hours lecture; 3 semester hours.

CEEN581. WATERSHED SYSTEMS MODELING. 3.0 Semester Hrs.

Equivalent with ESGN527,

Introduction to surface water modeling, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed modeling, parameter estimation and sensitivity analysis. Course is heavy on application of models across a range of diverse watersheds for streamflow and snowmelt predictions. In general, theoretical topics are covered in the first meeting each week, followed by hands-on application of concepts and models in the second meeting. Laptops and student Matlab licenses will be required for in-class activities. Prerequisite: none. 3 hours lecture per week; 3 semester hours.

CEEN582. MATHEMATICAL MODELING OF ENVIRONMENTAL SYSTEMS. 3.0 Semester Hrs.

Equivalent with ESGN528,

This is an advanced graduate-level course designed to provide students with hands-on experience in developing, implementing, testing, and using mathematical models of environmental systems. The course will examine why models are needed and how they are developed, tested, and used as decision-making or policy-making tools. Typical problems associated with environmental systems, such as spatial and temporal scale effects, dimensionality, variability, uncertainty, and data insufficiency, will be addressed. The development and application of mathematical models will be illustrated using a theme topic such as Global Climate Change, In Situ Bioremediation, or Hydrologic Systems Analysis. Prerequisites: CEEN580 and knowledge of basic statistics and computer programming. 3 hours lecture; 3 semester hours.

CEEN583. SURFACE WATER QUALITY MODELING. 3.0 Semester Hrs.

Equivalent with ESGN520,

This course will cover modeling of water flow and quality in rivers, lakes, and reservoirs. Topics will include introduction to common analytical and numerical methods used in modeling surface water flow, water quality, modeling of kinetics, discharge of waste water into surface systems, sedimentation, growth kinetics, dispersion, and biological changes in lakes and rivers. Prerequisites: CEEN480 or CEEN580 recommended. 3 hours lecture; 3 semester hours.

CEEN584. SUBSURFACE CONTAMINANT TRANSPORT. 3.0 Semester Hrs.

Equivalent with ESGN522,

This course will investigate physical, chemical, and biological processes governing the transport and fate of contaminants in the saturated and unsaturated zones of the subsurface. Basic concepts in fluid flow, groundwater hydraulics, and transport will be introduced and studied. The theory and development of models to describe these phenomena, based on analytical and simple numerical methods, will also be discussed. Applications will include prediction of extents of contaminant migration and assessment and design of remediation schemes. Prerequisites: CEEN580. 3 hours lecture; 3 semester hours.

CEEN589. WATER SUSTAINABILITY AND ENERGY PRODUCTION: CURRENT SCIENCE AND PRACTICE. 1.0 Semester Hr.

(II) This course is designed to provide students with valuable communication and professional skills while exploring in depth the topic of joint sustainability of water and unconventional petroleum energy production. A survey of current literature combined with key speakers will introduce the students to the field, while class sessions and practical exercises will help develop important communication, research, and interpersonal skills needed for future professionals. Course curriculum includes specific topics such as speaking/writing for a variety of audiences and critical thinking and analysis. This course is required for all ConocoPhillips - WE2ST Fellows, but is also open to any interested graduate students. 1 hour seminar; 1 semester hour.

CEEN590. CIVIL ENGINEERING SEMINAR. 1.0 Semester Hr.

(I) Introduction to contemporary and advanced methods used in engineering design. Includes, need and problem identification, methods to understand the customer, the market and the competition. Techniques to decompose design problems to identify functions. Ideation methods to produce form from function. Design for X topics. Methods for prototyping, modeling, testing and evaluation of designs. Embodiment and detailed design processes. Prerequisites: EGGN491 and EGGN492, equivalent senior design project experience or industrial design experience, graduate standing. 3 hours lecture; 3 semester hours. Taught on demand.

CEEN591. ENVIRONMENTAL PROJECT MANAGEMENT. 3.0 Semester Hrs.

Equivalent with ESGN571,

This course investigates environmental project management and decision making from government, industry, and contractor perspectives. Emphasis is on (1) economics of project evaluation; (2) cost estimation methods; (3) project planning and performance monitoring; (4) and creation of project teams and organizational/communications structures. Extensive use of case studies. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN592. ENVIRONMENTAL LAW. 3.0 Semester Hrs.

Equivalent with CEEN492,ESGN490,ESGN502,PEGN530,

This is a comprehensive introduction to U.S. Environmental Law, Policy, and Practice, especially designed for the professional engineer, scientist, planner, manager, consultant, government regulator, and citizen. It will prepare the student to deal with the complex system of laws, regulations, court rulings, policies, and programs governing the environment in the USA. Course coverage includes how our legal system works, sources of environmental law, the major USEPA enforcement programs, state/local matching programs, the National Environmental Policy Act (NEPA), air and water pollution (CAA, CWA), EPA risk assessment training, toxic/hazardous substances laws (RCRA, CERCLA, EPCRA, TSCA, LUST, etc.), and a brief introduction to international environmental law. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN593. ENVIRONMENTAL PERMITTING AND REGULATORY COMPLIANCE. 3.0 Semester Hrs.

Equivalent with ESGN593,

The purpose of this course is to acquaint students with the permit writing process, developing information requirements for permit applications, working with ambiguous regulations, negotiating with permit writers, and dealing with public comment. In addition, students will develop an understanding of the process of developing an economic and legally defensible regulatory compliance program. Prerequisite: CEEN592. 3 hours lecture; 3 semester hours.

CEEN594. RISK ASSESSMENT. 3.0 Semester Hrs.

Equivalent with ESGN501,

This course evaluates the basic principles, methods, uses, and limitations of risk assessment in public and private sector decision making. Emphasis is on how risk assessments are made and how they are used in policy formation, including discussion of how risk assessments can be objectively and effectively communicated to decision makers and the public. Prerequisite: CEEN592 and one semester of statistics. 3 hours lecture; 3 semester hours.

CEEN595. ANALYSIS OF ENVIRONMENTAL IMPACT. 3.0 Semester Hrs.

Equivalent with ESGN591,

Techniques for assessing the impact of mining and other activities on various components of the ecosystem. Training in the procedures of preparing Environmental Impact Statements. Course will include a review of pertinent laws and acts (i.e. Endangered Species Act, Coordination Act, Clean Air Act, etc.) that deal with environmental impacts. Prerequisite: none. 3 hours lecture, some field trips; 3 semester hours.

CEEN596. ENVIRONMENTAL SCIENCE AND ENGINEERING SEMINAR. 0.0 Semester Hrs.

Equivalent with ESGN590,

Research presentations covering current research in a variety of environmental topics.

CEEN598. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN610. INTERNATIONAL ENVIRONMENTAL LAW. 3.0 Semester Hrs.

Equivalent with ESGN602,

The course covers an introductory survey of International Environmental Law, including multi-nation treaties, regulations, policies, practices, and politics governing the global environment. It surveys the key issues of sustainable development, natural resources projects, transboundary pollution, international trade, hazardous waste, climate change, and protection of ecosystems, wildlife, and human life. New international laws are changing the rules for engineers, project managers, scientists, teachers, businesspersons, and others both in the US and abroad, and this course is especially designed to keep professionals fully, globally informed and add to their credentials for international work. Prerequisites: CEEN592. 3 hours lecture; 3 semester hours.

CEEN611. MULTIPHASE CONTAMINANT TRANSPORT. 3.0 Semester Hrs.

Equivalent with ESGN622,
Principles of multiphase and multicomponent flow and transport are applied to contaminant transport in the unsaturated and saturated zones. Focus is on immiscible phase, dissolved phase, and vapor phase transport of low solubility organic contaminants in soils and aquifer materials. Topics discussed include: capillarity, interphase mass transfer, modeling, and remediation technologies. Prerequisites: CEEN550 or equivalent, CEEN580 or CEEN584 or equivalent. 3 hours lecture; 3 semester hours.

CEEN698. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN699. ADVANCED INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

Equivalent with EGGN707C,ESGN707,
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Computer Science

DEGREES OFFERED

- Master of Science (Computer Science)
- Doctor of Philosophy (Computer Science)

PROGRAM OVERVIEW

The Computer Science Department offer the degrees Master of Science and Doctor of Philosophy in Computer Science. These degree programs demand academic rigor and depth yet also address real-world problems.

The Department has eight areas of research activity that stem from the core fields of Computer Science: (1) Algorithmic Robotics (2) Applied Algorithms (3) Augmented Reality (4) CS For All: CS Education (5) Cybersecurity (6) High Performance Computing (7) Machine Learning (8) Networked Systems.In many cases, individual research projects encompass more than one research area.

Research Areas:

ALGORITHMIC ROBOTICS
An interdisciplinary research area drawing from traditional computer science, engineering, and cognitive science. Research themes include artificial intelligence, human-robot interaction, and augmented reality, focusing on integrating computer vision and perception, learning and adaptation, natural language understanding and generation, and decision making into unified robot systems.

APPLIED ALGORITHMS
Research in Applied Algorithms and Data Structures combines classical algorithms research (characterized by the development of elegant algorithms and data structures accompanied by theory that provides mathematical guarantees about performance) and applications research (consisting of the actual development of software accompanied by empirical evaluations on appropriate benchmarks). Applications include cheminformatics and material science, crowdsourcing, data analytics, mobile computing, networking, security and privacy, the smart grid and VLSI design automation.

AUGMENTED REALITY
This area focuses on sensing information about the real world, augmenting visualization of reality by overlaying virtual information on the real world, and enabling user to interact with and digitally manipulate the information.

CS FOR ALL: COMPUTER SCIENCE EDUCATION
This area encompasses research on STEM recruitment and diversity, K-12 computing education, and computing/engineering education at the university level. Current projects include an on-campus computing outreach program tailored for girls across a broad age range; professional development opportunities for CS high school teachers; and incorporating ethics into core and elective computing courses.

CYBERSECURITY
Research includes usable security and privacy in web/mobile/cloud/cyber-physical systems, vulnerability measurement and analysis, and security-privacy education.

HIGH PERFORMANCE COMPUTING
Our high performance computing research focuses on using compiler and runtime techniques to optimize Big Data and machine learning applications on heterogeneous systems.

MACHINE LEARNING
Includes research in developing mathematical foundations and algorithm design needed for computers to learn. Focus areas include fundamental research in machine learning and numerical methods, as well as developing novel algorithms for bioinformatics, data mining, computer vision, biomedical image analysis, parallel computing, natural language processing, and data privacy.

NETWORKED SYSTEMS
Research aims to enable emerging wireless applications via networks and systems support, ranging from hardware design to algorithms development and software integration, from credible simulations to actual system deployment and testing.

PROGRAM DETAILS

The CS Department offers the degrees Master of Science and Doctor of Philosophy in Computer Science. The master's program is designed to prepare candidates for careers in industry or government or for further study at the Ph.D. level; both thesis and non-thesis options are available. The Ph.D. degree program is sufficiently flexible to prepare candidates for careers in industry, government, or academia. See the information that follows for full details on these two degrees.

Combined Program: The CS Department also offers combined BS/MS degree programs. These programs offer an expedited graduate school application process and allow students to begin graduate coursework while still finishing their undergraduate degree requirements. Details on this program can be found in the Mines Undergraduate Catalog.

PREREQUISITES

Requirements for Admission to CS: The minimum requirements for admission to the M.S. and Ph.D degrees in Computer Science are:

- Applicants must have a Bachelor's degree, or equivalent, from an accredited institution with a grade-point average of 3.0 or better on a 4.0 scale.
- Students are expected to have completed two semesters of calculus, along with courses in object-oriented programming and data structures, and upper level courses in at least three of the following areas: software engineering, numerical analysis, computer architecture, principles of programming languages, analysis of algorithms, and operating systems.
- Graduate Record Examination (Quantitative section) score of 151 or higher (or 650 on the old scale). Applicants who have graduated with an engineering degree from CSM within the past five years are not required to submit GRE scores.
- TOEFL score of 79 or higher (or 550 for the paper-based test or 213 for the computer-based test) for applicants whose native language is not English. In lieu of a TOEFL score, and IELTS score of 6.5 or higher will be accepted.
- For the Ph.D. program, prior research experience is desired but not required.

Admitted Students: The CS Department Graduate Committee may require that an admitted student take undergraduate remedial coursework to overcome technical deficiencies. The committee will decide whether to recommend regular or provisional admission.

Transfer Courses: Graduate level courses taken at other universities for which a grade equivalent to a "B" or better was received will be considered for transfer credit with approval of the Advisor and/or Thesis Committee, and CS Department Head, as appropriate. Transfer credits must not have been used as credit toward a Bachelor degree. For the M.S. degree, no more than nine credits may transfer. For the Ph.D. degree, up to 24 credit hours may be transferred. In lieu of transfer credit for individual courses, students who enter the Ph.D. program with a thesis-based master's degree from another institution may transfer up to 36 hours in recognition of the course work and research completed for that degree.

400-level Courses: As stipulated by the Mines Graduate School, students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department-approved 400-level course work.

Advisor and Thesis Committee: Students must have an Advisor from the CS faculty to direct and monitor their academic plan, research, and independent studies. Advisors must be full-time permanent members of the faculty. In this context, full-time permanent members of the faculty are those that hold the rank of professor, associate professor, assistant professor, research professor, associate research professor or assistant research professor. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors. A list of CS faculty by rank is available in the faculty tab of the catalog.

Master of Science (thesis option) students in CS must have at least three members on their Thesis Committee; the Advisor and one other member must be permanent faculty in the CS Department. CS Ph.D. Thesis Committees must have at least four members; the Advisor/co-advisor and two additional members must be permanent faculty in the CS Department, and one member must be outside the departmental faculty and serving as chair of the committee. Students who choose to have a minor program must select a representative from the minor area of study to serve on the Thesis Committee.

Degree Audit and Admission to Candidacy: Master students must complete the Degree Audit form (http://gradschool.mines.edu/Degree-Audit)by the posted deadline. Ph.D. students need to submit the Degree Audit form (http://gradschool.mines.edu/Degree-Audit) by the posted deadline and need to submit the Admission to Candidacy form (https://inside.mines.edu/GS-Candidacy-Addendum) two weeks prior to census day of the semester in which they want to be considered eligible for reduced registration.

Time Limit: As stipulated by the Mines Graduate School, a candidate for a Masters degree must complete all requirements for the degree within five years of the date of admission into the degree program. A candidate for a doctoral degree must complete all requirements for the degree within nine years of the date of admission into the degree program.

PROGRAM REQUIREMENTS

Master of Science - Computer Science

The M.S. degree in Computer Science (Thesis or Non-Thesis option) requires 30 credit hours. Requirements for the thesis M.S. are 21 hours of coursework plus 9 hours of thesis credit leading to an acceptable Master's thesis; thesis students are encouraged to find a thesis advisor and form a Thesis Committee by the end of the first year. The non-thesis option consists of two tracks: a Project Track and a Coursework Track. Requirements for the Project Track are 24 hours of coursework plus 6 hours of project credit; requirements for the Coursework Track are 30 hours of coursework. The following four core courses are required of all students. Students may choose elective courses from any CSCI graduate course offered by the Department. In addition, up to six credits of elective courses may be taken outside of CSCI. Lastly, a maximum of six Independent Study course units can be used to fulfill degree requirements.

CSCI406	ALGORITHMS	3.0
CSCI442	OPERATING SYSTEMS	3.0
CSCI561	THEORY OF COMPUTATION	3.0
CSCI564	ADVANCED COMPUTER ARCHITECTURE	3.0

M.S. Project Track: Students are required to take six credits of CSCI700 to fulfill the MS project requirement. (It is recommended that the six credits consist of two consecutive semesters of three credits each.) At most six credits of CSCI700 will be counted toward the Masters non-thesis degree. Deliverables include a report and a presentation to a committee of two CS faculty including the Advisor. Deliverables must be successfully completed in the last semester in which the student registers for CSCI700. A student must receive two "pass" votes (i.e., a unanimous vote) to satisfy the project option.

M.S. Thesis Defense: At the conclusion of the M.S. (Thesis Option), the student will be required to make a formal presentation and defense of her/his thesis research. A student must “pass” this defense to earn an M.S. degree.

CS Minor: A CS Minor at the Master's level requires a minimum of 9 semester hours of CSCI course work, of which, at leaset 6 semester hours of course work must be at the 500-level or above excluding independent studies and graduate seminars. Pursuant to Graduate School rules all minors must be approved by the student's advisor, home department head, and a faculty representative of the minor area of study. A minor may not be taken in the student's major area of study.

Doctor of Philosophy - Computer Science

The Ph.D. degree in Computer Science requires 72 credit hours of course work and research credits. Required course work provides a strong background in computer science. A course of study leading to the Ph.D. degree can be designed either for the student who has completed the master's degree or for the student who has completed the bachelor's degree. The following five courses are required of all students. Students who have taken equivalent courses at another institution may satisfy these requirements by transfer.

CSCI406	ALGORITHMS	3.0
CSCI442	OPERATING SYSTEMS	3.0
CSCI561	THEORY OF COMPUTATION	3.0
CSCI564	ADVANCED COMPUTER ARCHITECTURE	3.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS	1.0

Ph.D. Qualifying Examination: Students desiring to take the Ph.D. Qualifying Exam must have:

- (if required by your advisor) taken SYGN 501 The Art of Science (previously or concurrently),
- taken at least four CSCI 500-level courses at CSM (only one CSCI599 is allowed), and

- maintained a GPA of 3.5 or higher in all CSCI 500-level courses taken.

The Ph.D. Qualifying Exam must be taken no later than the fourth semester of study. Exception must be formally requested via email to the Qualifying Exam Committee Chair and approved by the Graduate Committee. The Ph.D. Qualifying Exam is offered once a semester. Each Ph.D. Qualifying Exam comprises of two research areas, chosen by the student. The exam consists of the following steps:

Step 1. A student indicates intention to take the CS Ph.D. Qualifying Exam by choosing two research interest areas from the following list: algorithms, education, high-performance computing, human-centered robotics, image processing, machine learning, and networks. This list is subject to change, depending on the current faculty research profile. Students must inform the CS Graduate Committee Chair of their intention to take the exam no later than the first class day of the semester.

Step 2. The Graduate Committee Chair creates an exam committee of (at least) four appropriate faculty. The exam committee assigns the student deliverables for both research areas chosen. The deliverables will be some combination from the following list:

- read a set of technical papers, make a presentation, and answer questions;
- complete a hands-on activity (e.g., develop research software) and write a report;
- complete a set of take-home problems;
- write a literature survey (i.e., track down references, separate relevant from irrelevant papers); and
- read a set of papers on research skills (e.g., ethics, reviewing) and answer questions.

Step 3. The student must complete all deliverables no later than the Monday of Dead Week.

Step 4. Each member of the exam committee makes a recommendation on the deliverables from the following list: strongly support, support, and do not support.To pass the Ph.D. Qualifying Exam, the student must have at least two "strongly supports" and no more than one "do not support". The student is informed of the decision no later than the Monday after finals week. A student can only fail the exam one time. If a second failure occurs, the student has unsatisfactory academic performance that results in an immediate, mandatory dismissal of the graduate student from the Ph.D. program.

Ph.D. Thesis Proposal: After passing the Qualifying Examination, the Ph.D. student is allowed up to 18 months to prepare a written Thesis Proposal and present it formally to the student's Thesis Committee and other interested faculty.

Admission to Candidacy: In addition to the Graduate School requirements, full-time Ph.D. students must complete the following requirements within two calendar years of enrolling in the Ph.D. program.

- Have a Thesis Committee appointment form on file in the Graduate Office:
- Have passed the Ph.D. Qualifying Exam demonstrating adequate preparation for, and satisfactory ability to conduct doctoral research.

Ph.D. Thesis Defense: At the conclusion of the student's Ph.D. program, the student will be required to make a formal presentation and defense of her/his thesis research. A student must “pass” this defense to earn a Ph.D. degree.

CS Minor: A CS Minor at the PhD level requires a minimum of 12 semester hours of CSCI course work, of which, 9 semester hours of course work must be at the 500-level or above excluding independent studies and graduate seminars. Pursuant to Graduate School rules all minors must be approved by the student's advisor, home department head, and a faculty representative of the minor area of study. A minor may not be taken in the student's major area of study.

Professor and Department Head

Tracy Camp

Professor

Dinesh Mehta

Associate professors

Qi Han

William Hoff

Assistant professors

Neil Dantam

Hua Wang

Thomas Williams

Bo Wu

Dejun Yang

Chuan Yue

Hao Zhang

Teaching Associate Professors

Wendy Fisher

Christopher Painter-Wakefield

Jeffrey Paone, Assistant Department Head

Emeritus Teaching Professor

Cyndi Rader

Professor of Practice

Mark Baldwin

Courses

CSCI507. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI437,CSCI512,EENG507,EENG512,EGGN512,
(I) 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. Prerequisites: Undergraduate level knowledge of linear algebra, statistics, and a programming language. 3 hours lecture; 3 semester hours.

CSCI508. ADVANCED TOPICS IN PERCEPTION AND COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with EENG508,
(II) This course covers advanced topics in perception and computer vision, emphasizing research advances in the field. The course focuses on structure and motion estimation, general object detection and recognition, and tracking. Projects will be emphasized, using popular software tools. Prerequisites: EENG507 or CSCI507. 3 hours lecture; 3 semester hours.

CSCI522. INTRODUCTION TO USABILITY RESEARCH. 3.0 Semester Hrs.
(I) An introduction to the field of Human-Computer Interaction (HCI). Students will review current literature from prominent researchers in HCI and will discuss how the researchers' results may be applied to the students' own software design efforts. Topics include usability testing, ubiquitous computing user experience design, cognitive walkthrough and talk-aloud testing methodologies. Students will work in small teams to develop and evaluate an innovative product or to conduct an extensive usability analysis of an existing product. Project results will be reported in a paper formatted for submission to an appropriate conference (UbiComp, SIGCSE, CHI, etc.). Prerequisite: CSCI 261 or equivalent. 3 hours lecture, 3 semester hours.

CSCI542. SIMULATION. 3.0 Semester Hrs.
Equivalent with MACS542,
(I) Advanced study of computational and mathematical techniques for modeling, simulating, and analyzing the performance of various systems. Simulation permits the evaluation of performance prior to the implementation of a system; it permits the comparison of various operational alternatives without perturbing the real system. Topics to be covered include simulation techniques, random number generation, Monte Carlo simulations, discrete and continuous stochastic models, and point/interval estimation. Offered every other year. Prerequisite: CSCI 262 (or equivalent) and MATH 323 (or MATH 530 or equivalent). 3 hours lecture; 3 semester hours.

CSCI544. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with MATH544,
This is an advanced computer graphics course in which students will learn a variety of mathematical and algorithmic techniques that can be used to solve fundamental problems in computer graphics. Topics include global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Students will learn about modern rendering and geometric modeling techniques by reading and discussing research papers and implementing one or more of the algorithms described in the literature.

CSCI546. WEB PROGRAMMING II. 3.0 Semester Hrs.
(I) This course covers methods for creating effective and dynamic web pages, and using those sites as part of a research agenda related to Humanitarian Engineering. Students will review current literature from the International Symposium on Technology and Society (ISTAS), American Society for Engineering Education (ASEE), and other sources to develop a research agenda for the semester. Following a brief survey of web programming languages, including HTML, CSS, JavaScript and Flash, students will design and implement a website to meet their research agenda. The final product will be a research paper which documents the students' efforts and research results. Prerequisite: CSCI 262. 3 hours lecture, 3 semester hours.

CSCI547. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.
Equivalent with MATH547,
Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on techniques applicable to spatial data such as scalar, vector and tensor fields. Topics include volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Students will learn about modern visualization techniques by reading and discussing research papers and implementing one of the algorithms described in the literature.

CSCI555. GAME THEORY AND NETWORKS. 3.0 Semester Hrs.
Equivalent with CSCI455,
(II) 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: CSCI406 Algorithms. 3 hours lecture; 3 semester hours.

CSCI561. THEORY OF COMPUTATION. 3.0 Semester Hrs.
(I) An introduction to abstract models of computation and computability theory; including finite automata (finite state machines), pushdown automata, and Turing machines. Language models, including formal languages, regular expressions, and grammars. Decidability and undecidability of computational problems. Prerequisite: CSCI/MATH358. 3 hours lecture; 3 semester hours.

CSCI562. APPLIED ALGORITHMS AND DATA STRUCTURES. 3.0 Semester Hrs.
(II) Industry competitiveness in certain areas is often based on the use of better algorithms and data structures. The objective of this class is to survey some interesting application areas and to understand the core algorithms and data structures that support these applications. Application areas could change with each offering of the class, but would include some of the following: VLSI design automation, computational biology, mobile computing, computer security, data compression, web search engines, geographical information systems. Prerequisite: MATH/CSCI406. 3 hours lecture; 3 semester hours.

CSCI563. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.
(I) Students are taught how to use parallel computing to solve complex scientific problems. They learn how to develop parallel programs, how to analyze their performance, and how to optimize program performance. The course covers the classification of parallel computers, shared memory versus distributed memory machines, software issues, and hardware issues in parallel computing. Students write programs for state of the art high performance supercomputers, which are accessed over the network. Prerequisite: Programming experience in C. 3 hours lecture; 3 semester hours.

CSCI564. ADVANCED COMPUTER ARCHITECTURE. 3.0 Semester Hrs.
The objective of this class is to gain a detailed understanding about the options available to a computer architect when designing a computer system along with quantitative justifications for the options. All aspects of modern computer architectures including instruction sets, processor design, memory system design, storage system design, multiprocessors, and software approaches will be discussed. Prerequisite: CSCI341. 3 hours lecture; 3 semester hours.

CSCI565. DISTRIBUTED COMPUTING SYSTEMS. 3.0 Semester Hrs.
(II) This course discusses concepts, techniques, and issues in developing distributed systems in large scale networked environment. Topics include theory and systems level issues in the design and implementation of distributed systems. Prerequisites: CSCI 442 or equivalent. 3 hours of lecture; 3 semester hours.

CSCI568. DATA MINING. 3.0 Semester Hrs.
Equivalent with MACS568,
(II) This course is an introductory course in data mining. It covers fundamentals of data mining theories and techniques. We will discuss association rule mining and its applications, overview of classification and clustering, data preprocessing, and several applicationspecific data mining tasks. We will also discuss practical data mining using a data mining software. Project assignments include implementation of existing data mining algorithms, data mining with or without data mining software, and study of data mining related research issues. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI571. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.
(I) Artificial Intelligence (AI) is the subfield of computer science that studies how to automate tasks for which people currently exhibit superior performance over computers. Historically, AI has studied problems such as machine learning, language understanding, game playing, planning, robotics, and machine vision. AI techniques include those for uncertainty management, automated theorem proving, heuristic search, neural networks, and simulation of expert performance in specialized domains like medical diagnosis. This course provides an overview of the field of Artificial Intelligence. Particular attention will be paid to learning the LISP language for AI programming. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI572. COMPUTER NETWORKS II. 3.0 Semester Hrs.
Equivalent with MACS572,
(II) This course covers the network layer, data link layer, and physical layer of communication protocols in depth. Detailed topics include routing (unicast, multicast, and broadcast), one hop error detection and correction, and physical topologies. Other topics include state-of-the-art communications protocols for emerging networks (e.g., ad hoc networks and sensor networks). Prerequisite: CSCI 471 or equivalent. 3 hours lecture; 3 semester hours.

CSCI573. HUMAN-CENTERED ROBOTICS. 3.0 Semester Hrs.
Equivalent with CSCI473,
(II) Human-centered robotics is an interdisciplinary area that bridges research and application of methodology from robotics, machine vision, machine learning, human-computer interaction, human factors, and cognitive science. Students will learn about fundamental research in human-centered robotics, as well as develop computational models for robotic perception, internal representation, robotic learning, human-robot interaction, and robot cognition for decision making. Students in CSCI 473 will be able to model and analyze human behaviors geared toward human-robot interaction applications. They will also be able to implement a working system using algorithms learnt to solve a given problem in human-centered robotics application. Students in CSCI 573 will get a more in-depth study into the theory of the algorithms. They will be able to compare the different algorithms to select the most appropriate one that can solve a specific problem. Prerequisites: CSCI262 and MATH201. 3 hours lecture; 3 semester hours.

CSCI574. THEORY OF CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with MATH574,
Students will draw upon current research results to design, implement and analyze their own computer security or other related cryptography projects. The requisite mathematical background, including relevant aspects of number theory and mathematical statistics, will be covered in lecture. Students will be expected to review current literature from prominent researchers in cryptography and to present their findings to the class. Particular focus will be given to the application of various techniques to real-life situations. The course will also cover the following aspects of cryptography: 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. Prerequisites: CSCI 262 plus undergraduate-level knowledge of statistics and discrete mathematics. 3 hours lecture, 3 semester hours.

CSCI575. MACHINE LEARNING. 3.0 Semester Hrs.
Equivalent with MACS575,
(II) The goal of machine learning research is to build computer systems that learn from experience and that adapt to their environments. Machine learning systems do not have to be programmed by humans to solve a problem; instead, they essentially program themselves based on examples of how they should behave, or based on trial and error experience trying to solve the problem. This course will focus on the methods that have proven valuable and successful in practical applications. The course will also contrast the various methods, with the aim of explaining the situations in which each is most appropriate. Prerequisites: CSCI262 and MATH201. 3 hours lecture; 3 semester hours.

CSCI576. WIRELESS SENSOR SYSTEMS. 3.0 Semester Hrs.
With the advances in computational, communication, and sensing capabilities, large scale sensor-based distributed environments are becoming a reality. Sensor enriched communication and information infrastructures have the potential to revolutionize almost every aspect of human life benefitting application domains such as transportation, medicine, surveillance, security, defense, science and engineering. Such a distributed infrastructure must integrate networking, embedded systems, distributed computing and data management technologies to ensure seamless access to data dispersed across a hierarchy of storage, communication, and processing units, from sensor devices where data originates to large databases where the data generated is stored and/or analyzed. Prerequisite: CSCI406, CSCI446, CSCI471. 3 hours lecture; 3 semester hours.

CSCI580. ADVANCED HIGH PERFORMANCE COMPUTING. 3.0 Semester Hrs.
This course provides students with knowledge of the fundamental concepts of high performance computing as well as hands-on experience with the core technology in the field. The objective of this class is to understand how to achieve high performance on a wide range of computational platforms. Topics will include sequential computers including memory hierarchies, shared memory computers and multicore, distributed memory computers, graphical processing units (GPUs), cloud and grid computing, threads, OpenMP, message passing (MPI), CUDA (for GPUs), parallel file systems, and scientific applications. 3 hours lecture; 3 semester hours.

CSCI585. INFORMATION SECURITY PRIVACY. 3.0 Semester Hrs.
(I) This course provides an introduction to the principles and best practices in information security and privacy. Lectures will include basic concepts of information security and privacy, fundamental security design principles, major topics in security and privacy, essential knowledge and skills, risk assessment and mitigation, policy development, and so on. In the classroom, students will also present and discuss a list of recent or classic research papers corresponding to the major topics in security and privacy. Outside of the classroom, students will work on homework assignments, security lab exercises, quizzes, research paper summaries, and a course project. Prerequisites: CSCI262, CSCI341. 3 hours lecture; 3 semester hours.

CSCI598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI691. GRADUATE SEMINAR. 1.0 Semester Hr.
Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

CSCI692. GRADUATE SEMINAR. 1.0 Semester Hr.
Equivalent with MACS692,MATH692,
Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

CSCI693. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.
Students will probe a range of current methodologies and issues in seismic data processing, with emphasis on underlying assumptions, implications of these assumptions, and implications that would follow from use of alternative assumptions. Such analysis should provide seed topics for ongoing and subsequent research. Topic areas include: Statistics estimation and compensation, deconvolution, multiple suppression, suppression of other noises, wavelet estimation, imaging and inversion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Prerequisite: none. 1 hour seminar; 1 semester hour.

CSCI698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI700. MASTERS PROJECT CREDITS. 1-6 Semester Hr.
(I, II, S) Project credit hours required for completion of the non-thesis Master of Science degree in Computer Science (Project Option). Project under the direct supervision of a faculty advisor. Credit is not transferable to any 400, 500, or 600 level courses. Repeatable for credit.

CSCI707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Electrical Engineering

DEGREES OFFERED

- Master of Science (Electrical Engineering)
- Doctor of Philosophy (Electrical Engineering)

PROGRAM OVERVIEW

The Electrical Engineering Department offer the degrees Master of Science and Doctor of Philosophy in Electrical Engineering. These degree programs demand academic rigor and depth yet also address real-world problems.

The Departments have four areas of research activity that stem from the core fields of Electrical Engineering: (1) Antennas and Wireless Communications, (2) Information and Systems Science and (3) Energy Systems and Power Electronics. In many cases, individual research projects encompass more than one research area.

Research Areas:

Antennas and Wireless Communications research areas include electromagnetics, antennas, microwave, and wireless communications. Applications address current academic, industry, and society needs. Examples include the design of antennas, antenna arrays, and microwave RF devices for communication and sensing applications.

Information and Systems Sciences is an interdisciplinary research area that encompasses the fields of control systems, communications, signal and image processing, compressive sensing, robotics, and mechatronics. Focus areas include intelligent and learning control systems, fault detection and system identification, computer vision and pattern recognition, sensor development, mobile manipulation and autonomous systems. Applications can be found in renewable energy and power systems, materials processing, sensor and control networks, bio-engineering, intelligent structures, and geosystems.

Energy Systems and Power Electronics is focused on both fundamental and applied research in the interrelated fields of conventional electric power systems and electric machinery, renewable energy and distributed generation, energy economics and policy issues, power quality, power electronics and drives. The overall scope of research encompasses a broad spectrum of electrical energy applications including investor-owned utilities, rural electric associations, manufacturing facilities, regulatory agencies, and consulting engineering firms.

Program Details

The Electrical Engineering Department offers the degrees Master of Science and Doctor of Philosophy in Electrical Engineering. The master's program is designed to prepare candidates for careers in industry or government or for further study at the Ph.D. level; both thesis and non-thesis options are available. The Ph.D. degree program is sufficiently flexible to prepare candidates for careers in industry, government, or academia. See the information that follows for full details on these four degrees.

Combined Program: The Electrical Engineering Department also offers combined BS/MS degree programs in three different tracks: (a) Information and Systems Sciences, (b) Energy Systems and Power Electronics, and (c) Antennas and Wireless Communications. These programs offer an expedited graduate school application process and allow students to begin graduate coursework while still finishing their undergraduate degree requirements. This program is described in the undergraduate catalog and is in place for Electrical Engineering students. The Physics combined program (B.S. in Engineering Physics and M.S. in EE) also offers similar tracks in Electrical Engineering. Details on this program can be found in the Mines undergraduate catalog, and course schedules for this program can be obtained in both the Physics and EE Departments.

Prerequisites

Requirements for Admission to EE: The minimum requirements for admission to the M.S. and Ph.D. degrees in Electrical Engineering are:

- A baccalaureate degree in engineering, computer science, a physical science, or math with a grade-point average of 3.0 or better on a 4.0 scale.
- Graduate Record Examination (Quantitative section) score of 151 or higher (or 650 on the old scale). Applicants who have graduated with an engineering degree from CSM within the past five years are not required to submit GRE scores.
- TOEFL score of 79 or higher (or 550 for the paper-based test or 213 for the computer-based test) for applicants whose native language is not English. In lieu of a TOEFL score, and IELTS score of 6.5 or higher will be accepted.
- For the Ph.D. program, prior research experience is desired but not required.

Admitted Students: The EE Department Graduate Committee may require that an admitted student take undergraduate remedial coursework to overcome technical deficiencies. The committee will decide whether to recommend regular or provisional admission.

Transfer Courses: Graduate level courses taken at other universities for which a grade equivalent to a "B" or better was received will be considered for transfer credit with approval of the Advisor and/or Thesis Committee, and EE Department Head, as appropriate. Transfer credits must not have been used as credit toward a Bachelor degree. For the M.S. degree, no more than nine credits may transfer. For the Ph.D. degree, up to 24 credit hours may be transferred. In lieu of transfer credit for individual courses, students who enter the Ph.D. program with a thesis-based master's degree from another institution may transfer up to 36 hours in recognition of the course work and research completed for that degree.

400-level Courses: As stipulated by the Mines Graduate School, students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department-approved 400-level course work.

Advisor and Thesis Committee: Students must have an Advisor from the EE faculty to direct and monitor their academic plan, research, and independent studies. Advisors must be full-time permanent members of the faculty. In this context, full-time permanent members of the faculty are those that hold the rank of professor, associate professor, assistant professor, research professor, associate research professor or assistant research professor. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors. A list of EE faculty by rank is available in the faculty tab in the catalog.

Master of Science (thesis option) students must have at least three members on their Thesis Committee; the Advisor and one other member must be permanent faculty in the EE Department. Students who choose to have a minor program must select a representative from the minor area of study to serve on the Thesis Committee. Ph.D. Thesis Committees must have at least four members; the Advisor and two additional members must be permanent faculty in the EE Department, and one member must be outside the departmental faculty and serving as chair of the committee. Students who choose to have a minor program must select a representative from the minor area of study to serve on the Thesis Committee.

Degree Audit and Admission to Candidacy: All degree students must submit required forms by the deadlines posted by the Office of Graduate Studies

Master students must complete the Degree Audit form (http://gradschool.mines.edu/Degree-Audit) by the posted deadline. Ph.D. students need to submit the Degree Audit form (http://gradschool.mines.edu/Degree-Audit) by the posted deadline and need to submit the Admission to Candidacy form (https://inside.mines.edu/GS-Candidacy-Addendum) by the first day of the semester in which they want to be considered eligible for reduced registration.

Time Limit: As stipulated by the Mines Graduate School, a candidate for a Masters degree must complete all requirements for the degree within five years of the date of admission into the degree program. A candidate for a doctoral degree must complete all requirements for the degree within nine years of the date of admission into the degree program.

Program Requirements

Master of Science – Electrical Engineering

The M.S. degree in Electrical Engineering (Thesis or Non-Thesis Option) requires 30 credit hours. Requirements for the thesis M.S. are 24 hours of coursework and six credit hours of thesis research. The non-thesis option requires 30 credit hours of coursework. A maximum of six credit hours of Independent Study can be used to fulfill degree requirements. There are three tracks in Electrical Engineering: (1) Antennas and Wireless Communications (AWC), (2) Energy Systems and Power Electronics (EPSE), and (3) Information and Systems Sciences (ISS). Students are encouraged to decide between tracks before pursuing an advanced degree. Students are also encouraged to speak to their Advisor and/or a member of the EE faculty before registering for classes and to select a permanent Advisor as soon as possible. The following set of courses is required of all students.

M.S. Thesis - Electrical Engineering

EENG707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	6.0
EE CORE: EE Core Courses (AWC track)		9.0
EE CORE: EE Core Courses (ESPE track)		9.0
EE CORE: EE Core Courses (ISS track)		12.0
TECHNICAL ELECTIVES Technical Electives must be approved by Thesis Committee		
EE TECH: EE Technical Electives (AWC track)		15.0
EE TECH: EE Technical Electives (ESPE track)		15.0
EE TECH: EE Technical Electives (ISS track)		12.0

M.S. Thesis Defense: At the conclusion of the M.S. (Thesis Option), the student will be required to make a formal presentation and defense of her/his thesis research.

M.S. Non-Thesis - Electrical Engineering

EE CORE: EE Core Courses (AWC track)	9.0
EE CORE: EE Core Courses (ESPE track)	9.0
EE CORE: EE Core Courses (ISS track)	12.0
TECHNICAL ELECTIVES Technical Electives must be approved by Advisor	
EE TECH: EE Technical Electives (AWC track)	15.0
EE TECH: EE Technical Electives (ESPE track)	15.0
EE TECH: EE Technical Electives (ISS track)	12.0
EE Electives (all tracks) Must be taught by an approved faculty member in EE	6.0

Doctor of Philosophy – Electrical Engineering

The Ph.D. degree in Electrical Engineering requires 72 credit hours of course work and research credits. A minimum of 36 credit hours of course work and a minimum of 24 credit hours of research is required. The remaining 12 credit hours required can be earned through research or coursework and students should consult with their Advisor and/or Thesis Committee. There are three tracks in Electrical Engineering: (1) Antennas and Wireless Communications (AWC), (2) Energy Systems and Power Electronics (ESPE), and (3) Information and Systems Sciences (ISS). Students are encouraged to decide between tracks before pursuing an advanced degree. Students are also encouraged to speak to their Advisor and/or a member of the EE faculty before registering for classes and to select a permanent Advisor as soon as possible. The following set of courses is required of all students.

EENG707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	24.0
EE CORE: EE Core Courses (AWC track)		9.0
EE CORE: EE Core Courses (ESPE track)		9.0
EE CORE: EE Core Courses (ISS track)		12.0
EE Technical Electives Technical Electives must be approved by Thesis Committee		
EE TECH: EE Technical Electives (AWC track)		27.0
EE TECH: EE Technical Electives (ESPE track)		27.0
EE TECH: EE Technical Electives (ISS track)		24.0

Ph.D. Qualifying Examination: Students wishing to enroll in the Electrical Engineering Ph.D. program will be required to pass a Qualifying Exam. Normally, full-time Ph.D. candidates will take the Qualifying Exam in their first year, but it must be taken within four semesters of entering the program. Part-time candidates will normally be expected to take the Qualifying Exam within no more than six semesters of entering the program.

The purpose of the Qualifying Exam is to assess some of the attributes expected of a successful Ph.D. student, including:

- To determine the student's ability to review, synthesize and apply fundamental concepts.
- To determine the creative and technical potential of the student to solve open-ended and challenging problems.
- To determine the student's technical communication skills.

The Qualifying Examination includes both written and oral sections. The written section is based on material from the EE Department's undergraduate Electrical Engineering degree. The oral part of the exam covers one or more papers from the literature chosen by the student and the student's Advisor. The student's Advisor and two additional Electrical Engineering faculty members (typically from the student's Thesis Committee representing their track) administer the oral exam.

Ph.D. Qualifying exams will be held each spring semester. In the event of a student failing the Qualifying exam, she/he will be given one further opportunity to pass the exam in the following spring semester. If a second failure occurs, the student has unsatisfactory academic performance that results in an immediate, mandatory dismissal of the graduate student from the Ph.D. program.

Ph.D. Thesis Proposal: After passing the Qualifying Examination, the Ph.D. student is allowed up to 18 months to prepare a written Thesis Proposal and present it formally to the student's graduate committee and other interested faculty.

Admission to Candidacy: In addition to the Graduate School requirements, full-time students must complete the following requirements within two calendar years of enrolling in the Ph.D. program.

- Have a Thesis Committee appointment form on file in the Graduate Office:
- Have passed the Ph.D. Qualifying Exam demonstrating adequate preparation for, and satisfactory ability to conduct doctoral research.

Ph.D. Thesis Defense: At the conclusion of the student's Ph.D. program, the student will be required to make a formal presentation and defense of her/his thesis research.

Electrical Engineering Courses

Required Core: Antennas and Wireless Communications Track

All students must take three of the following five core courses.

EENG525	ANTENNAS	3.0
EENG526	ADVANCED ELECTROMAGNETICS	3.0
EENG527	WIRELESS COMMUNICATIONS	3.0
EENG528	COMPUTATIONAL ELECTROMAGNETICS	3.0
EENG530	PASSIVE RF & MICROWAVE DEVICES	3.0

Required Core: Energy Systems and Power Electronics Track

All students must take three of the following four core courses.

EENG570	ADVANCED HIGH POWER ELECTRONICS	3.0
EENG580	POWER DISTRIBUTION SYSTEMS ENGINEERING	3.0
EENG581	POWER SYSTEM OPERATION AND MANAGEMENT	3.0
EENG583	ADVANCED ELECTRICAL MACHINE DYNAMICS	3.0

Under special circumstances, substitutions can be made with the approval of the student's advisor

Required Core: Information and Systems Sciences Track

All students must take:

EENG515	MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS	3.0

and choose at least three of the following:

EENG509	SPARSE SIGNAL PROCESSING	3.0
EENG511	CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS	3.0
EENG517	THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS	3.0
EENG519	ESTIMATION THEORY AND KALMAN FILTERING	3.0
EENG527	WIRELESS COMMUNICATIONS	3.0
EGGN589	DESIGN AND CONTROL OF WIND ENERGY SYSTEMS	3.0
MEGN544	ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL	3.0

The Electrical Engineering Department has approved the use of double-counting courses for students enrolled in the combined degree program and details can be found under Graduate Programs at https://electrical.mines.edu.

Professor and Department Head

Atef Elershbeni

Professors

Randy Haupt

P.K. Sen

Marcelo Simoes

Tyrone Vincent

Associate professors

Kathryn Johnson

Salman Mohagheghi

Michael Wakin

Assistant professors

Payam Nayeri

Gongguo Tang

Teaching Professors

Abdul Arkadan

Vibhuti Dave

Jeff Schowalter

Teaching Associate Professors

Stephanie Claussen

Chris Coulston

Research Professor

Mohammed Hadi

Emerita Professor

Catherine Skokan

Emeritus Professor

Ravel Ammerman

Courses

EENG504. ENGINEERING SYSTEMS SEMINAR - ELECTRICAL. 1.0 Semester Hr.
Equivalent with EGGN504E,
(I, II) This is a seminar forum for graduate students to present their research projects, critique others? presentations, understand the breadth of engineering projects both within their specialty area and across the Division, hear from leaders of industry about contemporary engineering as well as socio-economical and marketing issues facing today?s competitive global environment. In order to improve communication skills, each student is required to present a seminar in this course before his/her graduation from the Engineering graduate program. Prerequisite: Graduate standing. 1 hour seminar, 1 semester hour. Repeatable; maximum 1 hour granted toward degree requirements.

EENG507. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI507,CSCI512,EENG512,EGGN512,
(I) 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. Prerequisites: Undergraduate level knowledge of linear algebra, statistics, and a programming language. 3 hours lecture; 3 semester hours.

EENG508. ADVANCED TOPICS IN PERCEPTION AND COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI508,
(II) This course covers advanced topics in perception and computer vision, emphasizing research advances in the field. The course focuses on structure and motion estimation, general object detection and recognition, and tracking. Projects will be emphasized, using popular software tools. Prerequisites: EENG507 or CSCI507. 3 hours lecture; 3 semester hours.

EENG509. SPARSE SIGNAL PROCESSING. 3.0 Semester Hrs.
Equivalent with EGGN509,
(II) This course presents a mathematical tour of sparse signal representations and their applications in modern signal processing. The classical Fourier transform and traditional digital signal processing techniques are extended to enable various types of computational harmonic analysis. Topics covered include time-frequency and wavelet analysis, filter banks, nonlinear approximation of functions, compression, signal restoration, and compressive sensing. Prerequisites: EENG411 and EENG515. 3 hours lecture; 3 semester hours.

EENG511. CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS. 3.0 Semester Hrs.
(II) The course focuses on recognizing and solving convex optimization problems that arise in applications in various engineering fields. Covered topics include basic convex analysis, conic programming, duality theory, unconstrained optimization, and constrained optimization. The application part covers problems in signal processing, power and energy, machine learning, control and mechanical engineering, and other fields, with an emphasis on modeling and solving these problems using the CVX package. Offered Spring semester of even years. Prerequisites: EENG311 and EENG511. 3 hours lecture; 3 semester hours.

EENG515. MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN515,
(I) An introduction to mathematical methods for modern signal processing using vector space methods. Topics include signal representation in Hilbert and Banach spaces; linear operators and the geometry of linear equations; LU, Cholesky, QR, eigen- and singular value decompositions. Applications to signal processing and linear systems are included throughout, such as Fourier analysis, wavelets, adaptive filtering, signal detection, and feedback control.

EENG517. THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN517,
(II) This course will introduce and study the theory and design of multivariable and nonlinear control systems. Students will learn to design multivariable controllers that are both optimal and robust, using tools such as state space and transfer matrix models, nonlinear analysis, optimal estimator and controller design, and multi-loop controller synthesis. Spring semester of even years. Prerequisites: EENG417. 3 hours lecture; 3 semester hours.

EENG519. ESTIMATION THEORY AND KALMAN FILTERING. 3.0 Semester Hrs.
Equivalent with EGGN519,
(II) Estimation theory considers the extraction of useful information from raw sensor measurements in the presence of signal uncertainty. Common applications include navigation, localization and mapping, but applications can be found in all fields where measurements are used. Mathematic descriptions of random signals and the response of linear systems are presented. The discrete-time Kalman Filter is introduced, and conditions for optimality are described. Implementation issues, performance prediction, and filter divergence are discussed. Adaptive estimation and nonlinear estimation are also covered. Contemporary applications will be utilized throughout the course. Offered spring semester of odd years. Prerequisites: EENG515 and undergraduate knowledge of probability theory. 3 hours lecture; 3 semester hours.

EENG525. ANTENNAS. 3.0 Semester Hrs.
(I, II) This course provides an in depth introduction to the analysis and synthesis of antennas and antenna arrays. Students are expected to use MATLAB to model antennas and their performance. An extensive final project that involves experimental or computer demonstrations is required. EENG525 has more depth and required work than EENG425. EENG525 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on antenna and direction finding projects. Prerequisites: EGGN386 or GPGN302 or PHGN384. 3 hours lecture; 3 semester hours.

EENG526. ADVANCED ELECTROMAGNETICS. 3.0 Semester Hrs.
(II) In this course the fundamental theorems of electromagnetics are developed rigorously. Wave solutions are developed in Cartesian, cylindrical, and spherical coordinate systems for bounded and unbounded regions. Prerequisite: EENG386. 3 hours lecture; 3 semester hours.

EENG527. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.
Equivalent with EENG513,EGGN513,
(I, II) 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. EENG527 has more depth and required work than EENG427. EENG527 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on final project. Prerequisites: EENG386, EENG311, and EENG388. 3 hours lecture, 3 semester hours.

EENG528. COMPUTATIONAL ELECTROMAGNETICS. 3.0 Semester Hrs.
(I) This course provides the basic formulation and numerical solution for static electric problems based on Laplace, Poisson and wave equations and for full wave electromagnetic problems based on Maxwell? s equations. Variation principles methods, including the finite-element method and method of moments will be introduced. Field to circuit conversion will be discussed via the transmission line method. Numerical approximations based on the finite difference and finite difference frequency domain techniques will also be developed for solving practical problems. Prerequisite: EENG386. 3 hours lecture; 3 semester hours.

EENG529. 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. Prerequisites: EEBG385. 3 hours lecture; 3 semester hours.

EENG530. PASSIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.
(I) 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.

EENG570. ADVANCED HIGH POWER ELECTRONICS. 3.0 Semester Hrs.
Equivalent with EGGN585,
(I) Basic principles of analysis and design of circuits utilizing high power electronics. AC/DC, DC/AC, AC/AC, and DC/DC conversion techniques. Laboratory project comprising simulation and construction of a power electronics circuit. Prerequisites: EENG385; EENG389 or equivalent. 3 hours lecture; 3 semester hours. Fall semester even years.

EENG571. MODERN ADJUSTABLE SPEED ELECTRIC DRIVES. 3.0 Semester Hrs.
Equivalent with EGGN581,
An introduction to electric drive systems for advanced applications. The course introduces the treatment of vector control of induction and synchronous motor drives using the concepts of general flux orientation and the feedforward (indirect) and feedback (direct) voltage and current vector control. AC models in space vector complex algebra are also developed. Other types of drives are also covered, such as reluctance, stepper-motor and switched-reluctance drives. Digital computer simulations are used to evaluate such implementations. Pre-requisite: Familiarity with power electronics and power systems, such as covered in EENG480 and EENG470. 3 lecture hours; 3 semester hours. Spring semester of even years.

EENG572. RENEWABLE ENERGY AND DISTRIBUTED GENERATION. 3.0 Semester Hrs.
Equivalent with EGGN582,
A comprehensive electrical engineering approach on the integration of alternative sources of energy. One of the main objectives of this course is to focus on the inter-disciplinary aspects of integration of the alternative sources of energy which will include most common and also promising types of alternative primary energy: hydropower, wind power, photovoltaic, fuel cells and energy storage with the integration to the electric grid. Pre-requisite: It is assumed that students will have some basic and broad knowledge of the principles of electrical machines, thermodynamics, power electronics, direct energy conversion, and fundamentals of electric power systems such as covered in basic engineering courses plus EENG480 and EENG470. 3 lecture hours; 3 semester hours. Fall semester of odd years.

EENG573. ELECTRIC POWER QUALITY. 3.0 Semester Hrs.
Equivalent with EGGN580,
(II) Electric power quality (PQ) deals with problems exhibited by voltage, current and frequency that typically impact end-users (customers) of an electric power system. This course is designed to familiarize the concepts of voltage sags, harmonics, momentary disruptions, and waveform distortions arising from various sources in the system. A theoretical and mathematical basis for various indices, standards, models, analyses techniques, and good design procedures will be presented. Additionally, sources of power quality problems and some remedies for improvement will be discussed. The course bridges topics between power systems and power electronics. Prerequisite: EENG480 and EENG470. 3 lecture hours; 3 semester hours.

EENG580. POWER DISTRIBUTION SYSTEMS ENGINEERING. 3.0 Semester Hrs.

Equivalent with EGGN584,

This course deals with the theory and applications of problems and solutions as related to electric power distribution systems engineering from both ends: end-users like large industrial plants and electric utility companies. The primary focus of this course in on the medium voltage (4.16 kV ? 69 kV) power systems. Some references will be made to the LV power system. The course includes per-unit methods of calculations; voltage drop and voltage regulation; power factor improvement and shunt compensation; short circuit calculations; theory and fundamentals of symmetrical components; unsymmetrical faults; overhead distribution lines and power cables; basics and fundamentals of distribution protection. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Fall semester of odd years.

EENG581. POWER SYSTEM OPERATION AND MANAGEMENT. 3.0 Semester Hrs.

Equivalent with EGGN587,

(I) This course presents a comprehensive exposition of the theory, methods, and algorithms for Energy Management Systems (EMS) in the power grid. It will focus on (1) modeling of power systems and generation units, (2) methods for dispatching generating resources, (3) methods for accurately estimating the state of the system, (4) methods for assessing the security of the power system, and (5) an overview of the market operations in the grid. Prerequisite: EENG480. 3 lecture hours; 3 semester hours.

EENG582. HIGH VOLTAGE AC AND DC POWER TRANSMISSION. 3.0 Semester Hrs.

Equivalent with EGGN586,

This course deals with the theory, modeling and applications of HV and EHV power transmission systems engineering. The primary focus is on overhead AC transmission line and voltage ranges between 115 kV ? 500 kV. HVDC and underground transmission will also be discussed. The details include the calculations of line parameters (RLC); steady-state performance evaluation (voltage drop and regulation, losses and efficiency) of short, medium and long lines; reactive power compensation; FACTS devices; insulation coordination; corona; insulators; sag-tension calculations; EMTP, traveling wave and transients; fundamentals of transmission line design; HV and EHV power cables: solid dielectric, oil-filled and gas-filled; Fundamentals of DC transmission systems including converter and filter. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Fall semester of even years.

EENG583. ADVANCED ELECTRICAL MACHINE DYNAMICS. 3.0 Semester Hrs.

Equivalent with EGGN583,

This course deals primarily with the two rotating AC machines currently utilized in the electric power industry, namely induction and synchronous machines. The course is divided in two halves: the first half is dedicated to induction and synchronous machines are taught in the second half. The details include the development of the theory of operation, equivalent circuit models for both steady-state and transient operations, all aspects of performance evaluation, IEEE methods of testing, and guidelines for industry applications including design and procurement. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Spring semester of even years.

EENG584. POWER SYSTEM RISK MANAGEMENT. 3.0 Semester Hrs.

(II) This course presents a comprehensive exposition of the theory, methods, and algorithms for risk management in the power grid. The course will focus on: (1) power system stability analysis (steady state, dynamic, and transient), (2) analysis of internal and external threats to power systems, e.g. component failures, faults, natural hazards, cyber intrusions, (3) introduction to power system security assessment, (4) fundamentals of modeling risk, vulnerability assessment and loss calculations, (5) mitigating techniques before, during and after the course of major events and disturbances. Prerequisites: EENG480, EENG481. 3 hours lecture; 3 semester hours. Years to be Offered: Every Other Year.

EENG586. COMMUNICATION NETWORKS FOR POWER SYSTEMS. 3.0 Semester Hrs.

Advanced topics on communication networks for power systems including the fundamentals of communication engineering and signal modulation/ transfer, physical layer for data transfer (e.g., wireline, wireless, fiber optics), different communication topologies for power networks (e.g., client-server, peer-to-peer), fundamentals of SCADA system, data modeling and communication services for power system applications, common protocols for utility and substation automation, and cyber-security in power networks. Prerequisites: EENG480. 3 hours of lecture; 3 credit hours. Fall, odd years.

EENG587. POWER SYSTEMS PROTECTION AND RELAYING. 3.0 Semester Hrs.

Theory and practice of power system protection and relaying; Study of power system faults and symmetrical components; Fundamental principles and tools for system modeling and analysis pertaining to relaying, and industry practices in the protection of lines, transformers, generators, motors, and industrial power systems; Introduction to microprocessor based relaying, control, and SCADA. Prerequisites: EENG389. 3 hours of lecture; 3 credit hours. Spring, odd years.

EENG588. ENERGY POLICY, RESTRUCTURING AND DEREGULATION OF ELECTRICITY MARKET. 3.0 Semester Hrs.

The big picture of electric power, electricity and energy industry; Restructuring and Deregulation of electricity market; Energy Policy Acts and its impact on electricity market and pricing; Energy economics and pricing strategy; Public policy issues, reliability and security; Regulation. Prerequisites: EENG389. 3 hours of lecture; 3 credit hours. Fall, odd years.

EENG589. DESIGN AND CONTROL OF WIND ENERGY SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN589,

(II) Wind energy provides a clean, renewable source for electricity generation. Wind turbines provide electricity at or near the cost of traditional fossil-fuel fired power plants at suitable locations, and the wind industry is growing rapidly as a result. Engineering R&D can still help to reduce the cost of energy from wind, improve the reliability of wind turbines and wind farms, and help to improve acceptance of wind energy in the public and political arenas. This course will provide an overview of the design and control of wind energy systems. Offered Spring semester of odd years. 3 hours lecture; 3 semester hours.

EENG598. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG617. INTELLIGENT CONTROL SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN617,
Fundamental issues related to the design on intelligent control systems are described. Neural networks analysis for engi neering systems are presented. Neural-based learning, estimation, and identification of dynamical systems are described. Qualitative control system analysis using fuzzy logic is presented. Fuzzy mathematics design of rule-based control, and integrated human-machine intelligent control systems are covered. Real-life problems from different engineering systems are analyzed. Prerequisite: EENG517. 3 hours lecture; 3 semester hours. Taught on demand.

EENG618. NONLINEAR AND ADAPTIVE CONTROL. 3.0 Semester Hrs.
Equivalent with EGGN618,
This course presents a comprehensive exposition of the theory of nonlinear dynamical systems and the applications of this theory to adaptive control. It will focus on (1) methods of characterizing and understanding the behavior of systems that can be described by nonlinear ordinary differential equations, (2) methods for designing controllers for such systems, (3) an introduction to the topic of system identification, and (4) study of the primary techniques in adaptive control, including model-reference adaptive control and model predictive control. Prerequisite: EENG517. 3 hours lecture; 3 semester hours. Spring, even numbered years.

EENG683. COMPUTER METHODS IN ELECTRIC POWER SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN583,
This course deals with the computer methods and numerical solution techniques applied to large scale power systems. Primary focus includes load flow, short circuit, voltage stability and transient stability studies and contingency analysis. The details include the modeling of various devices like transformer, transmission lines, FACTS devices, and synchronous machines. Numerical techniques include solving a large set of linear or non-linear algebraic equations, and solving a large set of differential equations. A number of simple case studies (as per IEEE standard models) will be performed. Prerequisites: EENG583, EENG580 and EENG582 or equivalent; a strong knowledge of digital simulation techniques. 3 lecture hours; 3 semester hours. Taught on demand.

EENG698. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
Equivalent with EGGN707E,
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Engineering, Design, and Society

PROGRAM DESCRIPTION

The mission of the Division of Engineering, Design, and Society (EDS) is to engage in research, education, and outreach that inspires and empowers engineers and applied scientists to become innovative and impactful leaders in sociotechnical problem definition, solution, and design who can address the challenges of attaining a sustainable global society.

Courses

EDNS577. ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS577,
Analyzes the relationship between engineering and sustainable community development (SCD) from historical, political, ethical, cultural, and practical perspectives. Students will study and analyze different dimensions of sustainability, development, and "helping", and the role that engineering might play in each. Will include critical explorations of strengths and limitations of dominant methods in engineering problem solving, design and research for working in SCD. Through case-studies, students will analyze and evaluate projects in SCD and develop criteria for their evaluation. 3 hours lecture and discussion; 3 semester hours.

EDNS598. SPECIAL TOPICS IN ENGINEERING DESIGN & SOCIETY. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EDNS599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

Mechanical Engineering

Degrees Offered

- Master of Science (Mechanical Engineering)
- Doctor of Philosophy (Mechanical Engineering)

Program Overview

The Mechanical Engineering Department offers the Master of Science and Doctor of Philosophy degrees in Mechanical Engineering. The program demands academic rigor and depth yet also addresses real-world engineering problems. The department has four broad divisions of research activity that stem from core fields in Mechanical Engineering: (1) Biomechanics, (2) Thermal-Fluid Systems, (3) Solid Mechanics and Materials, and (4) Robotics, Automation, and Design. In many cases, individual research projects encompass more than one research area and elements from other disciplines.

Biomechanics focuses on the application of engineering principles to the musculoskeletal system and other connective tissues. Research activities include experimental, computational, and theoretical approaches with applications in the areas of rehabilitation engineering, computer-assisted surgery and medical robotics, patient-specific biomechanical modeling, intelligent prosthetics and implants, and bioinstrumentation. The Biomechanics group has strong research ties with other campus departments, the local medical community, and industry partners.

Robotics, Automation, and Design merges research from multiple areas of science and engineering. Topics include the design of robotic and automation system hardware and software, particularly for tasks that require some level of autonomy, intelligence, self-prognostics and decision making. Such capabilities are built upon integrated mechatronic systems that enable pro-active system responses to its environment and current state. These capabilities are applied in applications such as advanced robotics and manufacturing systems. Research in this division explores the science underlying the design process, implementation of mechanical and control systems to enable autonomy, and innovative computational analysis for automation, intelligence, and systems optimization.

Solid Mechanics and Materials develops novel computational and experimental solutions for problems in the mechanical behavior of advanced materials. Research in the division spans length scales from nanometer to kilometer, and includes investigations of microstructural effects on mechanical behavior, nanomechanics, granular mechanics, and continuum mechanics. Material-behavior models span length scales from the nano- and micro-scale, to the meso- and macro-scale. Much of the research is computational in nature using advanced computational methods such as molecular dynamics, finite-element, boundary-element and discrete-element methods. Strong ties exist between this group and the campus communities of applied mathematics, chemical engineering, materials science, metallurgy, and physics.

Thermal-Fluid Systems incorporates a wide array of multidisciplinary applications such as advanced energy conversion and storage, multi-phase fluid flows, materials processing, combustion, alternative fuels, and renewable energy. Research in thermal-fluid systems integrates the disciplines of thermodynamics, heat transfer, fluid mechanics, transport phenomena, chemical engineering, and materials science towards solving problems and making advances through experiments and computational modeling in the broad areas of energy conversion, fluid mechanics, and thermal transport. Research projects in this area specialize in some aspect of mechanical engineering but often have a strong interdisciplinary component in related fields such as Materials Science and Chemical Engineering.

Program Details

The Mechanical Engineering Department offers the degrees Master of Science and Doctor of Philosophy in Mechanical Engineering. The master's program is designed to prepare candidates for careers in industry or government or for further study at the Ph.D. level; both thesis and non-thesis options are available. The Ph.D. degree program is sufficiently flexible to prepare candidates for careers in industry, government, or academia. The following information provides details on these degrees.

Combined Program: The ME Department offers a combined degree program that allow students to earn an MS degree in Mechanical Engineering along with their Mines BS degree. This program enables students to begin graduate coursework while still finishing their undergraduate degree requirements. Students obtain specific engineering skills that complement their background. Details on the program can be found in the Mines Undergraduate Bulletin.

Prerequisites

Requirements for Admissions: The minimum requirements for admission into the M.S. and Ph.D. degrees in Mechanical Engineering are:

- a baccalaureate degree in engineering, computer science, a physical science, or mathematics with a minimum grade-point average of 3.0;
- Graduate Record Examination (Quantitative Reasoning) section score of 160 or higher. Applicants from an engineering program at CSM are not required to submit GRE scores;
- TOEFL score of 79 or higher (or 550 paper-based or 213 computer-based) for applicants whose native language is not English.

Program Requirements

Admitted Students: The Mechanical Engineering graduate admissions committee may require that an admitted student complete undergraduate remedial coursework to overcome technical deficiencies. Such coursework may not count toward the graduate degree. The committee will decide whether to recommend regular or provisional admission, and may ask the applicant to come to campus for an interview.

Transfer Courses: Graduate-level courses taken at other universities for which a grade equivalent to a "B" or better was received will be considered for transfer credit into the Mechanical Engineering Department. Approval from the Advisor and/or Thesis Committee and ME Department Head will be required as appropriate. Transfer credits must not have been used as credit toward a Bachelor degree. For the M.S. degree, no more than nine credits may transfer. For the Ph.D. degree, up to 24 credit hours may be transferred. In lieu of transfer credit for individual courses, students who enter the Ph.D. program with a thesis-based master's degree from another institution may transfer up to 36 hours in recognition of the course work and research completed for that degree.

400-level Courses: As stipulated by the CSM Graduate School, students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department-approved 400-level course work.

Master of Science Degree Requirements

The M.S. degree in Mechanical Engineering requires 30 credit hours. Requirements for the M.S.thesis option are 24 credit hours of coursework and 6 credit hours of thesis research. The M.S. non-thesis option requires 30 credit hours of coursework. *All M.S. students must complete nine credit hours of course work within one research division by selecting three courses listed under the Research Division Courses.*

Advisor and Thesis Committee: Students must have an Advisor from the Mechanical Engineering Department Faculty to direct and monitor their academic plan, research, and independent studies. The M.S. graduate Thesis Committee must have at least three members, two of whom must be permanent faculty in the Mechanical Engineering Department.

M.S. Thesis Degree

MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
MEGN503	GRADUATE SEMINAR Enrollment required every fall and spring semester	0.0
RESEARCH CORE	Courses from one Research Division List	9.0
TECHNICAL ELECTIVES	Technical Electives Courses approved by Advisor/Thesis Committee.	9.0
ME ELECTIVES	Any 400-level or above ME Course	3.0
MEGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	6.0
Total Semester Hrs		30.0

Thesis Defense: At the conclusion of the M.S. (Thesis Option), the student will be required to make a formal presentation and defense of her/his thesis research to his Advisor and Thesis Committee.

M.S. Non-Thesis Degree

MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
RESEARCH CORE	Course from one Research Division List	9.0
TECHNICAL ELECTIVES	Technical Electives Courses must be approved by Advisor.	9.0
ME ELECTIVES	Any ME 400-level or above course	9.0
Total Semester Hrs		30.0

Time Limit: As stipulated by the Mines Graduate School, a candidate for a Masters degree must complete all requirements for the degree within five years of the date of admission into the degree program.

Doctor of Philosophy Degree Requirements

The Ph.D. degree in Mechanical Engineering requires 72 credit hours of course work and research credits. A minimum of 36 credit hours of course work and 30 credit hours of research credits must be completed. A minimum of 12 of the 36 credit hours of required coursework must be taken at Colorado School of Mines. *All students must complete nine credit hours of course work within one research area by selecting 3 courses listed under the Research Division Courses.*

MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
MEGN503	GRADUATE SEMINAR Enrollment required every fall and spring semester	0.0
RESEARCH CORE	Courses from one Research Division List	9.0
TECHNICAL ELECTIVES	Technical Electives Must be approved by the Advisor/Thesis Committee.	24.0
MEGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	30.0
TOTAL CREDITS	Remaining credits can come from Research and/or Technical Electives	72.0

Timeline and Milestones: Ph.D. students must make adequate progress and reach appropriate milestones toward their degree by working with their faculty Advisor and thesis committee. The ME faculty has adopted a Ph.D. timeline that outlines milestones students must reach on a semester-by-semester basis. These milestones include selecting a permanent Advisor, establishing a thesis committee, completing the qualifying exam, presenting a research proposal, submitting appropriate graduation forms to move to admission to candidacy, a preliminary defense, and a final dissertation defense. Additional milestones also include journal publications requirements.

Advisor and Thesis Committee: Students must have an Advisor from the Mechanical Engineering Department Faculty to direct and monitor their academic plan, research, and independent studies. The Ph.D. graduate Thesis Committee must have at least four members; at least two members must be permanent faculty in the Mechanical Engineering Department, and at least one member must be from outside the department. This outside member must chair the committee. Students who choose to have a minor program must select a representative from the minor areas of study to serve on the Thesis Committee.

Qualifying Exam: Students enrolled in the Mechanical Engineering Ph.D. program will be required to pass a Qualifying Exam. The Ph.D. qualifying exam will be administered at a specific date during every semester by each research division independently. Each research division will appoint a Qualifying Exam chair, who oversees the process and ensures that the exam is administered fairly. Students must take the exam by no later than the end of their third semester in the Mechanical Engineering Ph.D. program. If the student fails the exam on their first attempt, they must retake the exam in the following semester with a maximum of two attempts to pass. One-semester extensions may be granted upon request to students who are enrolled as part-time or with non-ME backgrounds.

The purpose of the Qualifying Exam is to assess some of the attributes expected of a successful Ph.D. student, including:

- to determine the student's ability to review, synthesize and apply fundamental concepts;
- to determine the creative and technical potential of the student to solve open-ended and challenging problems;
- to determine the student's technical communication skills.

A written exam not to exceed 4.5 hours will be administered which will be divided into no more than five topical areas related to the research division, with topics announced in advance of the exam. The students will choose three topical areas to answer. Research divisions are encouraged to choose topical areas that relate to foundational undergraduate material linked to material in the core graduate courses required by that research division. Upon completion of the written exam, students will choose one paper out of a list of papers established by the research division faculty. Students will be given two weeks to write a two-page critical review of the paper which discusses possible extensions of the research.

Students, with a satisfactory performance on the written exam, will participate in an oral exam not to exceed two hours. The oral exam will be conducted by the qualifying exam committee and the student's Advisor. The research division will specify the format of the exam in advance of the exam.

Exam results of Pass, Conditional Pass or Fail will be provided to the student in a timely manner by the exam committee. A Conditional Pass will require the student to take a remedial plan.

Research Proposal: After passing the Qualifying Examination, the Ph.D. student will prepare a written Thesis Proposal and present it formally to the student's graduate committee and other interested faculty.

Degree Audit and Admission to Candidacy: Ph.D. students must complete the Degree Audit form (http://gradschool.mines.edu/Degree-Audit) by the posted deadlines and the Admission to Candidacy form (http://gradschool.mines.edu/Admission-to-Candidacy-form) by the first day of classes inof the semester in which they want to be considered eligible for reduced registration.

Additionally, full-time Ph.D. students must complete the following requirements within the first two calendar years after enrolling into the Ph.D. program:

- have a Thesis Committee appointment form on file in the Graduate Office;
- complete all prerequisite and core curriculum course requirements;
- demonstrate adequate preparation for, and satisfactory ability to conduct doctoral research; and
- be admitted into full candidacy for the degree.

Preliminary Defense: Prior to the final thesis defense, the PhD student will make an oral presentation to the student's graduate committee to summarize research accomplishments and work remaining.

Thesis Defense: At the conclusion of the student's Ph.D. program, the student will be required to make a formal presentation and defense of her/his thesis research. A student must "pass" this defense to earn a Ph.D. degree.

Time Limit: As stipulated by the Mines Graduate School, a candidate for a doctoral degree must complete all requirements for the degree within nine years of the date of admission into the degree program.

RESEARCH DIVISION COURSES

BIOMECHANIC COURSES	
MEGN514	CONTINUUM MECHANICS
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING ( )
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS
MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT
MEGN536	COMPUTATIONAL BIOMECHANICS ( )
MEGN540	MECHATRONICS
ROBOTICS AND AUTOMATION	
MEGN540	MECHATRONICS
MEGN544	ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL
MEGN545	ADVANCED ROBOT CONTROL
MEGN591	ADVANCED ENGINEERING DESIGN METHODS
MEGN592	RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN
MEGN593	ENGINEERING DESIGN OPTIMIZATION
SOLID MECHANICS AND MATERIALS	
MEGN511	FATIGUE AND FRACTURE
MEGN512	ADVANCED ENGINEERING VIBRATION
MEGN514	CONTINUUM MECHANICS
MEGN515	COMPUTATIONAL MECHANICS
MEGN517	INELASTIC CONSTITUTIVE RELATIONS
MEGN598	MICROMECHANICS/HOMOGENIZATION
THERMAL-FLUID SYSTEMS	
MEGN551	ADVANCED FLUID MECHANICS
MEGN552	VISCOUS FLOWAND BOUNDARY LAYERS
MEGN561	ADVANCED ENGINEERING THERMODYNAMICS
MEGN566	COMBUSTION
MEGN571	ADVANCED HEAT TRANSFER

Professor and Department Head

John Berger

George R. Brown Distinguished Professor

Robert J. Kee

Professors

Cristian V. Ciobanu

Gregory S. Jackson

Alexandra Newman

Brian G. Thomas

Associate Professor

Joel M. Bach

Gregory Bogin

Robert Braun

Mark Deinert

Anthony J. Petrella

Jason Porter

Anne Silverman

Aaron Stebner

Neal Sullivan

Ruichong "Ray" Zhang

Assistant Professor

Steven DeCaluwe

Andrew Osborne

Andrew Petruska

Paulo Tabares-Velasco

Nils Tilton

Garritt Tucker

Xiaoli Zhang

Teaching Professors

Kristine Csavina, Assistant Department Head

Ventzi Karaivanov

Teaching Associate Professors

Oyvind Nilsen

Derrick Rodriguez

Teaching Assistant Professors

Jeffrey Ackerman

Jeffrey Wheeler

Emeriti Professor

Robert King

Michael B. McGrath

Emerita Professor

Joan P. Gosink

Emeriti Associate Professor

Dave Munoz

Graham G.W. Mustoe

John P.H. Steele

Research Professor

George Gilmer

Research Associate Professors

Angel Abbud-Madrid

Sandrine Ricote

Huayang Zhu

Research Assistant Professors

Aminahmed Behnam

Christopher B. Dreyer

Branden Kappes

Canan Karakaya

Amy Schweikert

Affiliate Professor of Mechanical Engineering

Michael Mooney

Post-Doctoral Fellow

Gupta Ankit

Rajesh Jah

Yasuhito Suzuki

Courses

AMFG501. ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
(II) 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. The graduate section of this course differs from the undergraduate section in that graduate students perform AM-related research. While students complete quizzes and homework, they do not take a midterm or final exam. Prerequisites: MEGN200 and MEGN201 or equivalent project classes. 3 hours lecture; 3 semester hours.

AMFG598. 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.

DTCN501. INTRODUCTION TO DATA CENTER ENGINEERING. 3.0 Semester Hrs.
(I, II) This unique course will develop students' foundational knowledge in critical disciplines related to large-scale data center infrastructure design and performance. The course is intended for students with a B.S. in engineering, computer science, or applied and engineering physics who are interested in careers and/or opportunities in data center engineering and management. The course will incorporate real data center examples for introducing analysis of data center design and computing hardware and network requirements; engineering principles for data center power system design, distribution, and control; heat transfer systems for computer system thermal management and building HVAC; and large-scale data file organization, information system architecture, and network and software security. The course will conclude with lectures and an assignment related to sustainability and robustness for data center engineering and design. 3 hours lecture; 3 semester hours.

DTCN502. DATA CENTER INFRASTRUCTURE MANAGEMENT. 3.0 Semester Hrs.
(I, II) This course conveys the basic principles for operating, managing, and optimizing the hardware and software necessary for a large, modern data center. Students will learn how data center components are integrated and managed through software for various applications and in general for security, efficiency, adaptability, robustness, and sustainability. It is intended for graduate students with backgrounds in engineering or computer science. The students will become familiar with best practices in the industry and will demonstrate their knowledge by developing a operations management plan for a specific data center application. 3 hours lecture; 3 semester hours.

DTCN503. DATA CENTER ENGINEERING GRADUATE SEMINAR. 1.0 Semester Hr.

(I, II) The Data Center Engineering Seminar will provide students a broad knowledge of current industry and research developments in analysis, design, and operations of Data Center Engineering through once a week discussions and/or seminars from invited guest speakers presenting topics related to data center design, operations, and economics. Students will prepare several short reports on industry developments and/or academic research related to presentations and will deliver a technical presentation and lead a subsequent discussion on an approved topic relevant for the industry. Corequisite: DTCN501. 1 hour seminar; 1 semester hour.

DTCN591. DATA CENTER ENGINEERING DESIGN AND ANALYSIS. 2.0 Semester Hrs.

(I, II) In this graduate-level course, students will participate in a directed team-based project learning through planning, designing, and analyzing a large, modern data center for an industry- or government-relevant application. The course will build on content learned in pre-requisite courses on an Introduction to Data Center Engineering and on Data Center Infrastructure Management. Students will collaborate in multi-disciplinary teams to develop and present the design and analysis of a large, modern data center design for an industry or government application. 2 hours seminar; 2 semester hours.

MEGN501. ADVANCED ENGINEERING MEASUREMENTS. 3.0 Semester Hrs.

Equivalent with EGGN501,

(I) Introduction to the fundamentals of measurements within the context of engineering systems. Topics that are covered include: errors and error analysis, modeling of measurement systems, basic electronics, noise and noise reduction, and data acquisition systems. Prerequisite: EGGN250, EENG281 or equivalent, and MATH323 or equivalent; graduate student status. 3 hours lecture, 1 hour lab; 3 semester hours.

MEGN502. ADVANCED ENGINEERING ANALYSIS. 3.0 Semester Hrs.

Equivalent with EGGN502,

(I) Introduce advanced mathematical and numerical methods used to solve engineering problems. Analytic methods include series solutions, special functions, Sturm-Liouville theory, separation of variables, and integral transforms. Numerical methods for initial and boundary value problems include boundary, domain, and mixed methods, finite difference approaches for elliptic, parabolic, and hyperbolic equations, Crank-Nicolson methods, and strategies for nonlinear problems. The approaches are applied to solve typical engineering problems. Prerequisite: This is an introductory graduate class. The student must have a solid understanding of linear algebra, calculus, ordinary differential equations, and Fourier theory. 3 hours lecture.

MEGN503. GRADUATE SEMINAR. 0.0 Semester Hrs.

Equivalent with EGGN504M,

(I, II) This is a seminar forum for graduate students to present their research projects, critique others? presentations, understand the breadth of engineering projects both within their specialty area and across the Division, hear from leaders of industry about contemporary engineering as well as socio-economical and marketing issues facing today?s competitive global environment. In order to improve communication skills, each student is required to present a seminar in this course before his/her graduation from the Mechanical Engineering graduate program. Prerequisite: Graduate standing. 1 hour per week; 0 semester hours. Course is repeatable, but no coursework credit is awarded.

MEGN510. SOLID MECHANICS OF MATERIALS. 3.0 Semester Hrs.

Equivalent with EGGN543,

(II) Introduction to the algebra of vectors and tensors; coordinate transformations; general theories of stress and strain; principal stresses and strains; octahedral stresses; Hooke?s Law introduction to the mathematical theory of elasticity and to energy methods; failure theories for yield and fracture. Prerequisite: CEEN311 or equivalent, MATH225 or equivalent. 3 hours lecture; 3 semester hours.

MEGN511. FATIGUE AND FRACTURE. 3.0 Semester Hrs.

Equivalent with EGGN532,MTGN545,

(I) Basic fracture mechanics as applied to engineering materials, S-N curves, the Goodman diagram, stress concentrations, residual stress effects, effect of material properties on mechanisms of crack propagation. Prerequisite: none. 3 hours lecture; 3 semester hours. Fall semesters, odd numbered years.

MEGN512. ADVANCED ENGINEERING VIBRATION. 3.0 Semester Hrs.

Equivalent with EGGN546,

Vibration theory as applied to single- and multi-degree-of freedom systems. Free and forced vibrations to different types of loading-harmonic, impulse, periodic and general. Natural frequencies. Role of Damping. Importance of resonance. Modal superposition method. Prerequisite: MEGN315, 3 hours lecture; 3 semester hours.

MEGN513. KINETIC PHENOMENA IN MATERIALS. 3.0 Semester Hrs.

Equivalent with EGGN555,MLGN511,

(I) Linear irreversible thermodynamics, dorce-flux couplings, diffusion, crystalline materials, amorphous materials, defect kinetics in crystalline materials, interface kinetics, morphological evolution of interfaces, nucleation theory, crystal growth, coarsening phenomena and grain growth, solidification, spinodal decomposition. Prerequisites: MATH225: Differential equations (or equivalent), MLGN504/MTGN555/CBEN509: Thermodynamics (or its equivalent).

MEGN514. CONTINUUM MECHANICS. 3.0 Semester Hrs.

(I) This is a graduate course covering fundamentals of continuum mechanics and constitutive modeling. The goal of the course is to provide graduate students interested in fluid and solid mechanics with the foundation necessary to review and write papers in the field. Students will also gain experience interpreting, formulating, deriving, and implementing three-dimensional constitutive laws. The course explores six subjects: 1. Mathematical Preliminaries of Continuum Mechanics (Vectors, Tensors, Indicial Notation, Tensor Properties and Operations, Coordinate Transformations) 2. Stress (Traction, Invariants, Principal Values) 3. Motion and Deformation (Deformation Rates, Geometric Measures, Strain Tensors, Linearized Displacement Gradients) 4. Balance Laws (Conservation of Mass, Momentum, Energy) 5. Ideal Constitutive Relations (Frictionless & Linearly Viscous Fluids, Elasticity) 6. Constitutive Modeling (Formulation, Derivation, Implementation, Programming). 3 hours lecture, 3 semester hours.

MEGN515. COMPUTATIONAL MECHANICS. 3.0 Semester Hrs.
(I) A graduate course in computational mechanics with an emphasis on a studying the major numerical techniques used to solve problems that arise in mechanics and some related topical areas. Variational methods are applied throughout as a general approach in the development of many of these computational techniques. A wide range of problems are addressed in one- and two- dimensions which include linear and nonlinear elastic and elastoplastic steady state mechanics problems. Computational algorithms for time dependent problems such as transient dynamics and viscoplasticity are also addressed. In the latter part of the course an introduction to computational methods employing boundary integral equations, and particle methods for solving the mechanical behavior of multi-body systems are also given. Note all the software used in this course is written in MATLAB which has become a widely acceptable engineering programming tool. Prerequisites: MEGN312 and MEGN502. 3 lecture hours, 3 semester hours.

MEGN517. INELASTIC CONSTITUTIVE RELATIONS. 3.0 Semester Hrs.
(II) This is a graduate course on inelastic constitutive relations of solid materials. The goal of the course is to provide students working in solid mechanics and metallurgy with a foundation in theory and models of inelastic material behaviors. The behaviors we cover include plasticity, thermoelasticity, nonlinear elasticity, and phase transformations. We dive in at several length scales - crystal mechanics and phenomenological thermodynamic internal variable theory. We also discuss ties between models and state of the art experimental mechanics, including in-situ diffraction. We will cover both theory and numerical implementation strategies for the topics. Thus, students will gain experience interpreting, formulating, deriving, and implementing three-dimensional constitutive laws and crystal mechanics models. We will introduce many topics rather than focusing on a few such that students have a foot-in to dive deeper on their own, as they will do in the project. Prerequisites: MEGN514. 3 hours lecture, 3 semester hours.

MEGN520. BOUNDARY ELEMENT METHODS. 3.0 Semester Hrs.
Equivalent with EGGN545,
(II) Development of the fundamental theory of the boundary element method with applications in elasticity, heat transfer, diffusion, and wave propagation. Derivation of indirect and direct boundary integral equations. Introduction to other Green?s function based methods of analysis. Computational experiments in primarily two dimensions. Prerequisite: MEGN502. 3 hours lecture; 3 semester hours Spring Semester, odd numbered years.

MEGN521. INTRODUCTION TO DISCRETE ELEMENT METHODS (DEMS). 3.0 Semester Hrs.
Equivalent with EGGN535,
(I) Review of particle/rigid body dynamics, numerical DEM solution of equations of motion for a system of particles/rigid bodies, linear and nonlinear contact and impact laws dynamics, applications of DEM in mechanical engineering, materials processing and geo-mechanics. Prerequisites: CEEN311, MEGN315 and some scientific programming experience in C/C++ or Fortran. 3 hours lecture; 3 semester hours Spring semester of even numbered years.

MEGN530. BIOMEDICAL INSTRUMENTATION. 3.0 Semester Hrs.
Equivalent with BELS530,EGGN530,
The acquisition, processing, and interpretation of biological signals presents many unique challenges to the Biomedical Engineer. This course is intended to provide students with the knowledge to understand, appreciate, and address these challenges. At the end of the semester, students should have a working knowledge of the special considerations necessary to gathering and analyzing biological signal data. Prerequisites: EGGN250 MEL I, EENG281 Introduction to Electrical Circuits, Electronics, and Power, MEGN330 Introduction to Biomedical Engineering. 3 hours lecture; 3 semester hours. Fall odd years.

MEGN531. PROSTHETIC AND IMPLANT ENGINEERING. 3.0 Semester Hrs.
Equivalent with BELS527,EGGN527,
Prosthetics and implants for the musculoskeletal and other systems of the human body are becoming increasingly sophisticated. From simple joint replacements to myoelectric limb replacements and functional electrical stimulation, the engineering opportunities continue to expand. This course builds on musculoskeletal biomechanics and other BELS courses to provide engineering students with an introduction to prosthetics and implants for the musculoskeletal system. At the end of the semester, students should have a working knowledge of the challenges and special considerations necessary to apply engineering principles to augmentation or replacement in the musculoskeletal system. Prerequisites: Musculoskeletal Biomechanics [MEGN430], 3 hours lecture; 3 semester hours. Fall even years.

MEGN532. EXPERIMENTAL METHODS IN BIOMECHANICS. 3.0 Semester Hrs.
(I) Introduction to experimental methods in biomechanical research. Topics include experimental design, hypothesis testing, motion capture, kinematic models, ground reaction force data collection, electromyography, inverse dynamics calculations, and applications. Strong emphasis on hands-on data collection and technical presentation of results. The course will culminate in individual projects combining multiple experimental measurement techniques. Prerequisite: Graduate Student Standing. 3 hours lecture; 3.0 semester hours.

MEGN535. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.
Equivalent with BELS526,EGGN526,
(II) Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties and interactions with the environment to construct detailed computer models and simulations. The course will culminate in individual class projects related to each student?s individual interests. Prerequisites: MEGN315 and MEGN330. 3 hours lecture; 3 semester hours.

MEGN536. COMPUTATIONAL BIOMECHANICS. 3.0 Semester Hrs.
Equivalent with BELS528,EGGN528,
Computational Biomechanics provides and introduction to the application of computer simulation to solve some fundamental problems in biomechanics and bioengineering. Musculoskeletal mechanics, medical image reconstruction, hard and soft tissue modeling, joint mechanics, and inter-subject variability will be considered. An emphasis will be placed on understanding the limitations of the computer model as a predictive tool and the need for rigorous verification and validation of computational techniques. Clinical application of biomechanical modeling tools is highlighted and impact on patient quality of life is demonstrated. Prerequisite: MEGN424, MEGN330. 3 hours lecture; 3 semester hours. Fall odd years.

MEGN537. PROBABILISTIC BIOMECHANICS. 3.0 Semester Hrs.

Equivalent with EGGN529,

(II) MEGN537. PROBABILISTIC BIOMECHANICS The course introduces the application of probabilistic analysis methods in biomechanical systems. All real engineering systems, and especially human systems, contain inherent uncertainty due to normal variations in dimensional parameters, material properties, motion profiles, and loading conditions. The purpose of this course is to examine methods for including these sources of variation in biomechanical computations. Concepts of basic probability will be reviewed and applied in the context of engineering reliability analysis. Probabilistic analysis methods will be introduced and examples specifically pertaining to musculoskeletal biomechanics will be studied. Prerequisites: MEGN436/BELS428 or MEGN536/BELS528. 3 hours lecture, 3 semester hours. Spring even years.

MEGN540. MECHATRONICS. 3.0 Semester Hrs.

Equivalent with EGGN521,

(II) A course focusing on implementation aspects of mechatronic and control systems. Significant lab component involving embedded C programming on a mechatronics teaching platform, called a "haptic paddle", a single degree-of-freedom force-feedback joystick. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours.

MEGN544. ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL. 3.0 Semester Hrs.

Equivalent with EGGN518,

(I) Mathematical representation of robot structures. Mechanical analysis including kinematics, dynamics, and design of robot manipulators. Representations for trajectories and path planning for robots. Fundamentals of robot control including, linear, nonlinear and force control methods. Introduction to off-line programming techniques and simulation. Prerequisite: EENG307 and MEGN441. 3 hours lecture; 3 semester hours.

MEGN545. ADVANCED ROBOT CONTROL. 3.0 Semester Hrs.

Equivalent with EGGN514,

The focus is on mobile robotic vehicles. Topics covered are: navigation, mining applications, sensors, including vision, problems of sensing variations in rock properties, problems of representing human knowledge in control systems, machine condition diagnostics, kinematics, and path planning real time obstacle avoidance. Prerequisite: EENG307. 3 hours lecture; 3 semester hours. Spring semester of odd years.

MEGN551. ADVANCED FLUID MECHANICS. 3.0 Semester Hrs.

(I) This first year graduate course covers the fundamentals of incompressible fluid mechanics with a focus on differential analysis and building a strong foundation in the prerequisite concepts required for subsequent study of computational fluid dynamics and turbulence. The course is roughly divided into four parts covering (i) the governing equations of fluid mechanics, (ii) Stokes flows and ideal-fluid flows, (iii) boundary layer flows, and (iv) hydrodynamic stability and transition to turbulence. Prerequisites: MEGN351. 3 hours lecture; 3 semester hours.

MEGN552. VISCOUS FLOW AND BOUNDARY LAYERS. 3.0 Semester Hrs.

Equivalent with EGGN552,

(I) This course establishes the theoretical underpinnings of fluid mechanics, including fluid kinematics, stress-strain relationships, and derivation of the fluid-mechanical conservation equations. These include the mass-continuity and Navier-Stokes equations as well as the multi-component energy and species-conservation equations. Fluid-mechanical boundary-layer theory is developed and applied to situations arising in chemically reacting flow applications including combustion, chemical processing, and thin-film materials processing. Prerequisite: MEGN451, or CBEN430. 3 hours lecture; 3 semester hours.

MEGN553. INTRODUCTION TO COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS AND TRANSPORT PHENOMENA. 3.0 Semester Hrs.

Equivalent with EGGN573,

(II) Introduction to Computational Fluid Dynamics (CFD) for graduate students with no prior knowledge of this topic. Basic techniques for the numerical analysis of fluid flows. Acquisition of hands-on experience in the development of numerical algorithms and codes for the numerical modeling and simulation of flows and transport phenomena of practical and fundamental interest. Capabilities and limitations of CFD. Prerequisite: MEGN451. 3 hours lecture; 3 semester hours.

MEGN560. DESIGN AND SIMULATION OF THERMAL SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN570,

In this course the principles of design, modeling, analysis, and optimization of processes, devices, and systems are introduced and applied to conventional and advanced energy conversion systems. It is intended to integrate conservation principles of thermodynamics (MEGN361) with the mechanism relations of fluid mechanics (MEGN351) and heat transfer (MEGN471). The course begins with general system design approaches and requirements and proceeds with mathematical modeling, simulation, analysis, and optimization methods. The design and simulation of energy systems is inherently computational and involves modeling of thermal equipment, system simulation using performance characteristics, thermodynamic properties, mechanistic relations, and optimization (typically with economic-based objective functions). Fundamental principles for steady-state and dynamic modeling are covered. Methods for system simulation which involves predicting performance with a given design (fixed geometry) are studied. Analysis methods that include Pinch Technology, Exergy Analysis, and Thermo-economics are examined and are considered complementary to achieving optimal designs. Optimization encompasses objective function formulation, systems analytical methods, and programming techniques. System optimization of the design and operating parameters of a configuration using various objective functions are explored through case studies and problem sets. Economics and optimization for analyses and design of advanced energy systems, such as Rankine and Brayton cycle power plants, combined heat and power, refrigeration and geothermal systems, fuel cells, turbomachinery, and heat transfer equipment are a focus. 3 lecture hours; 3 credit hours.

MEGN561. ADVANCED ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.

(I) First year graduate course in engineering thermodynamics that emphasizes a greater depth of study of undergraduate subject matter and an advancement to more complex analyses and topics. The course begins with fundamental concepts, 1st and 2nd Law analyses of processes, devices, and systems and advances to equations of state, property relations, ideal and non-ideal gas mixtures, chemically reacting systems, and phase equilibrium. Historical and modern contexts on the development and advancements of thermodynamic concepts are given. Fundamental concepts are explored through the analysis of advanced thermodynamic phenomena and use of computational tools to solve more realistic problems. Prerequisites: MEGN351, MEGN361, and MEGN471. 3 hours lecture; 3 semester hours.

MEGN566. COMBUSTION. 3.0 Semester Hrs.
Equivalent with EGGN566,
(I) An introduction to combustion. Course subjects include: the development of the Chapman-Jouget solutions for deflagration and detonation, a brief review of the fundamentals of kinetics and thermochemistry, development of solutions for diffusion flames and premixed flames, discussion of flame structure, pollutant formation, and combustion in practical systems. Prerequisite: MEGN451 or CBEN430. 3 hours lecture; 3 semester hours.

MEGN567. HVAC AND BUILDING ENERGY SYSTEMS. 3.0 Semester Hrs.
(I) First or second year graduate course that covers the fundamentals of building energy systems, moist air processes, heating, ventilation, and air conditioning (HVAC) systems and the use of numerical models for heat and mass transfer to analyze advanced building technologies such as phase change materials, green roofs or cross laminated timber. Prerequisites: MEGN351, MEGN361, MEGN471. 3 hours lecture; 3 semester hours.

MEGN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN569,CHEN569,EGGN569,MLGN569,MTGN569,
(I) 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 credit hours.

MEGN570. ELECTROCHEMICAL SYSTEMS ENGINEERING. 3.0 Semester Hrs.
(I) In this course, students will gain fundamental, quantitative insight into the operation of electrochemical devices for engineering analysis across a range of length scales and applications. The course will use the development of numerical models as a lens through which to view electrochemical devices. However, the course will also deal extensively with "real world" systems and issues, including experimental characterization, system optimization and design, and the cyclical interplay between models and physical systems. The course begins by establishing the equations that govern device performance at the most fundamental level, describing chemical and electrochemical reactions, heat transfer, transport of charged and neutral species, and material properties in operating devices. Subsequently, these equations will be used to discuss and analyze engineering issues facing three basic types of electrochemical devices: fuel cells, batteries, and sensors. At each juncture will evaluate our equations to determine when simpler models may be more suitable. Throughout the semester, concepts will be applied in homework assignments, including an over-arching, semester-long project to build detailed numerical models for an application of each student's choosing. 3 hours lecture; 3 semester hours.

MEGN571. ADVANCED HEAT TRANSFER. 3.0 Semester Hrs.
Equivalent with EGGN571,
(II) An advanced course in heat transfer that supplements topics covered in MEGN471. Derivation and solution of governing heat transfer equations from conservation laws. Development of analytical and numerical models for conduction, convection, and radiation heat transfer, including transient, multidimensional, and multimode problems. Introduction to turbulence, boiling and condensation, and radiative transfer in participating media. 3 lecture hours; 3 credit hours.

MEGN583. ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
(II) 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. The graduate section of this course differs from the undergraduate section in that graduate students perform AM-related research. While students complete quizzes and homework, they do not take a midterm or final exam. Prerequisites: MEGN200 and MEGN201 or equivalent project classes. 3 hours lecture; 3 semester hours.

MEGN585. NETWORK MODELS. 3.0 Semester Hrs.
(I) 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. Offered every other year. 3 hours lecture; 3 semester hours.

MEGN586. LINEAR OPTIMIZATION. 3.0 Semester Hrs.
(I) We address 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. 3 hours lecture; 3 semester hours.

MEGN587. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN487,
(II) We address 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. Prerequisite: MATH111. 3 hours lecture; 3 semester hours.

MEGN588. INTEGER OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN488,
(I) We address the formulation of integer programming models, the brand-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. Prerequisite: none. 3 hours lecture; 3 semester hours. Years to be Offered: Every Other Year.

MEGN591. ADVANCED ENGINEERING DESIGN METHODS. 3.0 Semester Hrs.

Equivalent with EGGN503,
(I) Introduction to contemporary and advanced methods used in engineering design. Includes, need and problem identification, methods to understand the customer, the market and the competition. Techniques to decompose design problems to identify functions. Ideation methods to produce form from function. Design for X topics. Methods for prototyping, modeling, testing and evaluation of designs. Embodiment and detailed design processes. Prerequisites: EGGN491 and EGGN492, equivalent senior design project experience or industrial design experience, graduate standing. 3 hours lecture; 3 semester hours. Taught on demand.

MEGN592. RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN. 3.0 Semester Hrs.

(I) The importance of understanding, assessing, communicating, and making decisions based in part upon risk, reliability, robustness, and uncertainty is rapidly increasing in a variety of industries (e.g.: petroleum, electric power production, etc.) and has been a focus of some industries for many decades (e.g.: nuclear power, aerospace, automotive, etc). This graduate class will provide the student with a technical understanding of and ability to use common risk assessment tools such as Reliability Block Diagrams (RBD), Failure Modes and Effects Analysis (FMEA), and Probabilistic Risk Assessment (PRA); and new tools being developed in universities including Function Failure Design Methods (FFDM), Function Failure Identification and Propagation (FFIP), and Uncoupled Failure Flow State Reasoning (UFFSR) among others. Students will also be provided with a high-level overview of what risk really means and how to contextualize risk information. Methods of communicating and making decisions based in part upon risk information will be discussed. 3 hours lecture, 3 semester hours.

MEGN593. ENGINEERING DESIGN OPTIMIZATION. 3.0 Semester Hrs.

Equivalent with EGGN593,
The application of gradient, stochastic and heuristic optmization algorithms to linear and nonlinear optimization problems in constrained and unconstrained design spaces. Students will consider problems in constrained and unconstrained design spaces. Students will consider problems with continuous, integer and mixed-integer variables, problems with single or multiple objectives and the task modeling design spaces and constraints. Design optimization methods are becoming of increasing importance in engineering design and offer the potential to reduce design cycle times while improving design quality by leveraging simulation and historical design data. Prerequisites: Experience wiht computer programming languages, graduate or senior standing. 3 hours lecture; 3 semester hours.

MEGN598. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MEGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MEGN686. ADVANCED LINEAR OPTIMIZATION. 3.0 Semester Hrs.

(II) As an advanced course in optimization, we expand upon topics in linear programming: advanced formulation, the dual simplex method, the interior point method, algorithmic tuning for linear programs (including numerical stability considerations), column generation, and Dantzig-Wolfe decomposition. Time permitting, dynamic programming is introduced. Applications of state-of-the-art hardware and software emphasize solving real-world problems in areas such as manufacturing, mining, energy, transportation and logistics, and the military. Computers are used for model formulation and solution. Offered every other year. Prerequisite: MEGN586. 3 hours lecture; 3 semester hours.

MEGN688. ADVANCED INTEGER OPTIMIZATION. 3.0 Semester Hrs.

(II) As an advanced course in optimization, we expand upon topics in integer programming: advanced formulation, strong integer programming formulations (e.g., symmetry elimination, variable elimination, persistence), in-depth mixed integer programming cuts, rounding heuristics, constraint programming, and decompositions. Applications of state-of-the-art hardware and software emphasize solving real-world problems in areas such as manufacturing, mining, energy, transportation and logistics, and the military. Computers are used for model formulation and solution. Prerequisite: MEGN588. 3 hours lecture; 3 semester hours. Years to be Offered: Every Other Year.

MEGN698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MEGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

Equivalent with EGGN707M,
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

SPRS501. SPACE RESOURCES FUNDAMENTALS. 3.0 Semester Hrs.
(I, II) This course provides an overview of the space resources field, including the current knowledge of available resources in the Solar System, extraction and utilization systems under development, economic and technical feasibility studies, legal and policy issues, and space exploration architectures that may be enabled by utilizing extraterrestrial resources in the near future. The course will build broad knowledge and develop confidence in problem solving in the space resources field. Prerequisite: Working knowledge of physical sciences, engineering fields, or economics at an advanced undergraduate level, with basic numerical analysis skills using a programming language or spreadsheet calculations. 3 hours lecture; 3 semester hours.

SPRS502. SPACE SYSTEMS ENGINEERING. 3.0 Semester Hrs.
(I, II) This course conveys the fundamentals of the systems engineering process as applied to large, complex space systems. It is intended for graduate students with various backgrounds. The students will become familiar with full scope of the systems engineering process from requirements definition, system design, system analysis through system verification. The process will be illustrated with real-world examples from current space systems with an emphasis on systems relevant to the development of space resources. Co-requisite: SPRS501. 3 hours lecture; 3 semester hours.

SPRS503. SPACE RESOURCES GRADUATE SEMINAR. 1.0 Semester Hr.
(I, II) The Space Resources Graduate Seminar will engage graduate students in the program with current research and developments related to space resources assessment, extraction, and utilization. The course, which will meet once a week, will provide students opportunities to engage with invited guest speakers who are industry, government, and academic leaders in the space resources field. Students will be asked to prepare a few short reports on research related to guest speaker seminars. Students will also prepare and deliver at least one technical presentation on their own work and/or that of others and lead a discussion on the topic of interest. This course will instill knowledge and confidence in the students to enable them to critique, articulate, and present concepts and relevant research and development in space resources. Co-requisite: SPRS501. 1 hour seminar; 1 semester hour.

SPRS591. SPACE RESOURCES DESIGN AND ANALYSIS I. 2.0 Semester Hrs.
(I, II) This course will provide graduate students in the program with directed team-based project learning by exploring the design, planning, and analysis of a mission, process, or systems for space resources assessment, extraction, and/or utilization. The course will meet formally twice a week for one hour and include a 10-15 minute discussion on relevant design aspects of space mission, processes, and/or systems. In this regard, it will build on content learned in the Space Resources Fundamental and Space Systems Engineering courses. Students will collaborate in multi-disciplinary teams of up to 5 students. Teams will be advised by the course instructor with significant industrial aerospace design experience and supported by faculty affiliated with the Space Resources program from relevant disciplines on campus. For teams with students in space resource economics, detailed economic analysis will be incorporated into those projects. Student teams will prepare a preliminary design, planning and analysis report early in the semester, one interim progress report, and a final report and project presentation. This course will guide the students and teach them good design and analysis practices and principles for missions and/or systems related to space resources. Co-requisites: SPRS501 and SPRS502. 2 hours lecture; 2 semester hours.

SPRS592. SPACE RESOURCES DESIGN AND ANALYSIS II. 3.0 Semester Hrs.
(I, II) The Space Resources Design and Analysis II course will provide graduate students in the MS-NT and Ph.D. degree programs in Space Resources with an independent design and analysis project. This project, which will be guided by the course instructor and a technical advisor, will enable the student to delve deeply into a particular system related to space resources prospecting, extraction, processing, and/or utilization. As much as possible, projects will be coordinated with industrial or government agency partners who are collaborating with the program. The course will involve weekly meetings with the course instructor and all students in the course where ideas are exchanged and progress discussed within the context of design and analysis principles learned in the pre-requisite course SPRS591. Students will be partnered with a faculty member affiliated with the Space Resources program. The student will prepare a final report and presentation to present to industry collaborators, space resources faculty, and other students in the course. The final report and/or presentation as appropriate will be converted to a journal or conference publication and/or presentation and resources from the program will support student costs for publishing and/or presenting the work. Prerequisite: SPRS591. 3 hours lecture; 3 semester hours.

College of Earth Resource Sciences and Engineering

The College of Earth Resource Sciences & Engineering (CERSE) is home to some of Mines' oldest and most established areas of study, while also offering unparalleled expertise in new and emerging fields. Our college combines robust technical, material and policy expertise to educate students to work collaboratively across disciplines and solve complex global challenges. Our vision is to make a bold impact on energy and earth resources education and research, both nationally and internationally, and to build the pipeline of future industry leaders.

CERSE is a strong, three-pronged structure comprised of six academic departments: it is technical (Geology, Geophysics, and Petroleum Engineering) and hands-on with materials (Mining Engineering and Petroleum Engineering) combined with public policy-driven focus (Economics & Business and Humanities, Arts & Social Sciences). CERSE contributes to Mines' global reach and strategic partnerships around the world.

- Colorado Geological Survey (http://coloradogeologicalsurvey.org)
- Economics & Business (http://econbus.mines.edu)
- Geology & Geological Engineering (http://geology.mines.edu)
- Geophysics (http://geophysics.mines.edu)
- Humanities, Arts, and Social Sciences (http://hass.mines.edu)
- Mining Engineering (http://mining.mines.edu)
- Petroleum Engineering (http://petroleum.mines.edu)

The students and faculty in CERSE are working collaboratively toward a shared vision of academic excellence. We invite you to learn more about each department's extraordinary capabilities and accomplishments by visiting their websites.

Economics and Business

Degrees Offered

- Master of Science (Mineral and Energy Economics)
- Doctor of Philosophy (Mineral and Energy Economics)
- Master of Science (Engineering and Technology Management)

Mineral and Energy Economics Program Description

In an increasingly global and technical world, government and industry leaders in the mineral and energy areas require a strong foundation in economic and business skills. The Division offers such skills in unique programs leading to M.S. and Ph.D. degrees in Mineral and Energy Economics. Course work and research emphasizes the use of models to aid in decision making. Beyond the core courses students in the Mineral and Energy Economics Program may select, in consultation with their advisor from a set of electives that fit their specialized needs and educational goals. This may include advanced courses in Applied Economics, Finance, and Operations Research.

Engineering and Technology Management Program Description

The Division also offers an M.S. degree in Engineering and Technology Management (ETM). The ETM degree program is designed to integrate the technical elements of engineering practice with the managerial perspective of modern engineering and technology management. A major focus is on the business and management principles related to this integration. The ETM Program provides the analytical tools and managerial perspective needed to effectively function in a highly competitive and technologically complex business economy.

Students in the ETM Program may select elective courses from two areas of focus: Engineering Management and Optimization or Technology Management and Innovation. The Optimization courses focus on developing knowledge of advanced operations research, optimization, and decision making techniques applicable to a wide array of business and engineering problems. The Engineering Management courses emphasize valuable techniques for managing large engineering and technical projects effectively and efficiently. The Strategy and Innovation courses teach the correct match between organizational strategies and structures to maximize the competitive power of technology with a particular emphasis on management issues associated with the modern business enterprise.

Combined Degree Program Option

Mines undergraduate students have the opportunity to begin work on a M.S. degree in Mineral and Energy Economics or Engineering & Technology Management while completing their Bachelor's degree at Mines. The Mineral and Energy Economics Combined Degree Program provides the vehicle for students to use undergraduate coursework as part of their Graduate Degree curriculum. For more information please contact the EB Office or visit econbus.mines.edu.

Mineral and Energy Economics Program Description

In an increasingly global and technical world, government and industry leaders in the mineral and energy areas require a strong foundation in economic and business skills. The Division offers such skills in unique programs leading to M.S. and Ph.D. degrees in Mineral and Energy Economics. Course work and research emphasizes the use of models to aid in decision making. Beyond the core courses students in the Mineral and Energy Economics Program select, in consultation with their advisor, from a set of electives that fit their specialized needs and educational goals. This may include advanced courses in Applied Economics, Finance, and Operations Research.

Mineral and Energy Economics Program Requirements

M.S. Degree Students choose from either the thesis or non-thesis option in the Master of Science (M.S.) Program and are required to complete a minimum total of 36 credits (a typical course has 3 credits). Initial admission is only to the non-thesis program. Admission to the thesis option requires subsequent application after at least one full-time equivalent semester in the program.

Non-thesis option	
Core courses	15.0
Approved electives*	21.0
Total Semester Hrs	36.0

Thesis option	
Core courses	15.0
Research credits	12.0
Approved electives*	9.0
Total Semester Hrs	36.0

* Non-thesis M.S. students may apply six elective credits toward a nine hour minor in another department. See below for details.

Further Degree Requirements

All thesis and non-thesis students in the Mineral and Energy Economics Program are required to attend the Distinguished Lecture Series sponsored by the Payne Institute for Earth Resources and the Division of Economics and Business. This series facilitates active involvement in the Mineral and Energy Economics Program by top researchers and influential leaders in the policy arena. The Program Director will outline attendance requirements at the beginning of each fall semester.

Ph.D. Degree Doctoral students develop a customized curriculum to fit their needs. The degree requires a minimum of 72 graduate credit hours that includes course work and a thesis.

Course work (requires advisor and committee approval)	
First year Core courses	15.0
Extended Core	3.0
Approved electives	18.0
Total Semester Hrs	36.0

Research credits

Research credits	36.0

The student's faculty advisor and the doctoral thesis committee must approve the student's program of study and the topic for the thesis.

Qualifying Examination Process

Upon completion of the first-year core course work, Ph.D. students must pass a first set of qualifying written examinations (collectively Qualifier 1). A student will receive one of four possible grades on the Micro Economics and Quantitative Methods examinations: High Pass, Pass, Marginal Fail, or Fail. A student receiving a marginal fail on one, or both of the examinations will have the opportunity to retake the relevant examination(s) within a year of the initial attempt. Students receiving a marginal fail should consult their adviser as to whether to retake exams during the winter or summer breaks. A student receiving a Fail, or consecutive Marginal Fails, will be dismissed from the program. Consistent with university policy, the faculty will grade and inform students of qualification examination results within two weeks of the examinations.

Upon completion of the extended core (typically in the second year), Ph.D. students must pass a second qualifying written examination (Qualifier II). A student will receive one of four possible grades on Qualifier II: High Pass, Pass, Marginal Fail, or Fail. A student receiving a Marginal Fail on Qualifier II will have the opportunity to retake the exam, or relevant portions of the exam as determined by the examination committee, within a year of the initial attempt. Students receiving a marginal fail should consult their advisor as to whether to retake exams during the winter or summer breaks. A student receiving a Fail or consecutive Marginal Fails, on Qualifier II will be dismissed from the program. Consistent with university policy, the faculty will grade and inform students of qualification examination results within two weeks of the examinations.

Following a successful thesis-proposal defense and prior to the final thesis defense, a student is required to present a completed research paper (or dissertation chapter) in a research seminar at CSM. The research presentation must be considered satisfactory by at least three CSM faculty members in attendance.

Minor from Another Department

Non-thesis M.S. students may apply six elective credits towards a nine hour minor in another department. A minor is ideal for those students who want to enhance or gain knowledge in another field while gaining the economic and business skills to help them move up the career ladder. For example, a petroleum, chemical, or mining engineer might want to learn more about environmental engineering, a geophysicist or geologist might want to learn the latest techniques in their profession, or an economic policy analyst might want to learn about political risk. Students should check with the minor department for the opportunities and requirements.

Transfer Credits

Non-thesis M.S. students may transfer up to 6 credits (9 credits for a thesis M.S.). The student must have achieved a grade of B or better in all graduate transfer courses and the transfer credit must be approved by the student's advisor and the Division Director. Students who enter the Ph.D. program may transfer up to 24 hours of graduate-level course work from other institutions toward the Ph.D. degree subject to the restriction that those courses must not have been used as credit toward a Bachelor degree. The student must have achieved a grade of B or better in all graduate transfer courses and the transfer must be approved by the student's Doctoral Thesis Committee and the Division Director.

Unsatisfactory Progress

In addition to the institutional guidelines for unsatisfactory progress as described elsewhere in this bulletin. Unsatisfactory progress will be assigned to any full-time student who does not pass the first year core courses on time. EBGN509, EBGN510 and EBGN521 in the first fall semester of study; and EBGN590 in the first spring semester of study. Unsatisfactory progress will also be assigned to any students who do not complete requirements as specified in their admission letter. Part-time students develop an approved course plan with their advisor.

Ph.D. Students are expected to take the first set of qualification examinations (Qualifier I) in the first summer following eligibility. Unsatisfactory progress may be assigned to any student who does not meet this expectation. Consistent with university policy, consideration will be given to students who have documented illness or other qualifying personal event that prevents them from taking Qualifier I. A marginal fail on a qualification examination does not trigger the assignment of unsatisfactory progress. Unsatisfactory progress will, however be assigned to a student who fails to retake a marginally failed examination in the next available summer offering.

Combined BS/MS Program

Students enrolled in CSM's Combined Undergraduate/ Graduate Program may double count 6 hours from their undergraduate course-work towards the non-thesis graduate program provided the courses satisfy the M.S. requirements.

Dual Degree

The M.S. degree may be combined with a second degree from the IFP School (Paris, France) in Petroleum Economics and Management (see http://www.ifp.fr). This dual-degree program is geared to meet the needs of industry and government. Our unique program trains the next generation of technical, analytical and managerial professionals vital to the future of the petroleum and energy industries

These two world-class institutions offer a rigorous and challenging program in an international setting. The program gives a small elite group of students a solid economics foundation combined with quantitative business skills, the historical and institutional background, and the interpersonal and intercultural abilities to in the fast paced, global world of oil and gas.

Degrees: After studying in English for only 16 months (8 months at CSM and 8 months at IFP) the successful student of Petroleum Economics and Management (PEM) receives not 1 but 2 degrees:

- Masters of Science in Mineral and Energy Economics from CSM and
- Diplôme D'Ingénieur or Mastère Spécialisé from IFP

Important: Applications for admission to the joint degree program should be submitted for consideration by March 1st to begin the program the following fall semester in August. A limited number of students are selected for the program each year.

Prerequisites for the Mineral and Energy Economics Programs

Students must have completed the following undergraduate prerequisite courses prior to beginning the program with a grade of B or better:

1. Principles of Microeconomics;
2. One semester of college-level Calculus;
3. Probability and Statistics

Students will only be allowed to enter in the spring semester if they have completed all three prerequisites courses previously, as well as undergraduate courses in mathematical economics and natural resource economics.

Required Course Curriculum in Mineral and Energy Economics

All M.S. and Ph.D. students in Mineral and Energy Economics are required to take a set of core courses that provide basic tools for the more advanced and specialized courses in the program.

1. M.S. Curriculum

a. Core Courses

EBGN509	MATHEMATICAL ECONOMICS	3.0
EBGN510	NATURAL RESOURCE ECONOMICS	3.0
EBGN521	MICROECONOMICS OF MINERAL AND ENERGY MARKETS	3.0
EBGN590	ECONOMETRICS I	3.0
EBGN690	ECONOMETRICS II * An alternative econometrics elective may be substituted for EBGN690 (for example, EBGN694 Time-series Econometrics)	3.0
Total Semester Hrs		15.0

b. Approved Electives (21 credits for M.S. non-thesis option or 9 credits for M.S. thesis option)

The student, in consultation with their advisor, will choose six additional courses (four for thesis students). A minimum of two courses must be Advanced Economics courses. The program of study can be customized to fit the individual student's educational goals, but must be approved by their advisor.

2. Ph.D. Curriculum

a. Common Core Courses

EBGN509	MATHEMATICAL ECONOMICS	3.0
EBGN510	NATURAL RESOURCE ECONOMICS	3.0
EBGN521	MICROECONOMICS OF MINERAL AND ENERGY MARKETS	3.0
EBGN590	ECONOMETRICS I	3.0
EBGN690	ECONOMETRICS II * An alternative econometrics elective may be substituted for EBGN690 (for example, EBGN694 Time-series Econometrics)	3.0
Total Semester Hrs		15.0

b. Extended Core Courses

EBGN611	ADVANCED MICROECONOMICS	3.0
Total Semester Hrs		3.0

c. Approved Electives (18 credit hours)

The student, in consultation with their advisor, will choose six additional courses. A minimum of two courses must be Advanced Economics courses. The program of study can be customized to fit the individual student's educational goals, but must be approved by their advisor.

Engineering and Technology Management (ETM) Master of Science Program Requirements

Students choose either the thesis or non-thesis option and complete a minimum of 30 credit hours. Initial admission is only to the non-thesis program. Admission to the thesis option requires subsequent application after admission to the ETM program.

Non-thesis option	
Core courses	15.0
Elective courses	15.0
Total Semester Hrs	30.0

Thesis option	
Core courses	15.0
Research credits	6.0
Elective courses	9.0
Total Semester Hrs	30.0

Students must receive approval from their advisor in order to apply non-EB Division courses towards their ETM degree. Thesis students are required to complete 6 credit hours of thesis credit and complete a Master's level thesis under the direct supervision of the student's thesis advisor.

Further Degree Requirements

All thesis and non-thesis ETM M.S. students have four additional degree requirements:

1. the Executive-in-Residence seminar series;
2. the ETM Communications workshop;
3. the Leadership and Team Building workshop;
4. Economic Evaluation workshop.

All students are required to attend the ETM Program Executive-in-Residence seminar series during their first spring semester of study in the ETM Program. The Executive-in-Residence series features executives from industry who pass on insight and knowledge to graduate students preparing for positions in industry. This series facilitates active involvement in the ETM program by industry executives through teaching, student advising activities and more. Every spring semester the Executive-in-Residence will present a number of seminars on a variety of topics related to leadership and strategy in the engineering and technology sectors.

In addition, all students in their first fall semester of study in the ETM Program are required to attend a Communications workshop, a Leadership and Team Building workshop and an Economic Evaluation workshop. The Communications workshop will provide students with a comprehensive approach to good quality communication skills, including presentation proficiency, organizational skills, professional writing skills, meeting management, as well as other professional communication abilities. This workshop is designed to better prepare students for the ETM learning experience and their professional careers. The Leadership and Team Building workshop consists of non-competitive games, trust exercises and problem solving challenges and will introduce students to one another and provide opportunities to learn and practice leadership and team skills. Finally, the Economic Evaluation workshop provides an overview engineering economics and the criteria used to evaluate investment decisions in technology-based industries.

Combined Degree Students

Students in an approved combined degree program who take ETM classes from the list below[1] (p.) as undergraduate electives are able to double count six of these credits towards the MS degree in ETM.

EBGN525	BUSINESS ANALYTICS	3.0
EBGN553	PROJECT MANAGEMENT	3.0
EBGN560	DECISION ANALYSIS	3.0
EBGN563	MANAGEMENT OF TECHNOLOGY	3.0

Additional courses may be added subject to the approval of the ETM Program Director.

Transfer Credits

Students who enter the M.S. in Engineering and Technology Management program may transfer up to 6 graduate course credits into the degree program. The student must have achieved a grade of B or better in all graduate transfer courses and the transfer credit must be approved by the student's advisor and the Director of the ETM Program.

Required Curriculum M.S. Degree Engineering and Technology Management

Thesis and non-thesis students are required to complete the following 15 hours of core courses which ideally should be taken at the first available opportunity:

a. Core Courses

EBGN525	BUSINESS ANALYTICS	3.0
EBGN540	ACCOUNTING AND FINANCE	3.0
EBGN553	PROJECT MANAGEMENT	3.0
EBGN563	MANAGEMENT OF TECHNOLOGY	3.0
EBGN585	ENGINEERING AND TECHNOLOGY MANAGEMENT CAPSTONE (to be taken during the final semester of coursework)	3.0
Total Semester Hrs		15.0

b. Elective courses (15 credits required for non-thesis option or 9 credits required for thesis option)

Engineering Management and Analytic Methods		
EBGN526	STOCHASTIC MODELS IN MANAGEMENT SCIENCE	3.0
EBGN528	INDUSTRIAL SYSTEMS SIMULATION	3.0
EBGN555	LINEAR PROGRAMMING	3.0
EBGN559	SUPPLY CHAIN MANAGEMENT	3.0
EBGN560	DECISION ANALYSIS	3.0
EBGN571	MARKETING ANALYTICS	3.0
Technology Management and Innovation		
EBGN515	ECONOMICS AND DECISION MAKING	3.0
EBGN566	TECHNOLOGY ENTREPRENEURSHIP	3.0
EBGN567	BUSINESS LAW AND ETHICS	3.0
EBGN572	INTERNATIONAL BUSINESS STRATEGY	3.0
EBGN573	ENTREPRENEURIAL FINANCE	3.0
EBGN576	MANAGING AND MARKETING NEW PRODUCT DEVELOPMENTS	3.0
EBGN598	SPECIAL TOPICS IN ECONOMICS AND BUSINESS	3.0

Professor

Roderick G. Eggert, Interim Division Director, Viola Vestal Coulter Professor

Associate Professors

Jared C. Carbone

Michael B. Heeley

Assistant Professors

Tulay Flamand

Ben Gilbert

Richard Hunt

Ian A. Lange

Peter Maniloff

Steven M. Smith

Teaching Associate Professors

Scott Houser

Becky Lafrancois

Andrew Pederson

Sid Saleh

Professors Emeriti

Carol A. Dahl

Graham Davis

Franklin J. Stermole

John E. Tilton

Michael R. Walls

Courses

EBGN504. ECONOMIC EVALUATION AND INVESTMENT DECISION METHODS. 3.0 Semester Hrs.
Time value of money concepts of present worth, future worth, annual worth, rate of return and break-even analysis are applied to after-tax economic analysis of mineral, petroleum and general investments. Related topics emphasize proper handling of (1) inflation and escalation, (2) leverage (borrowed money), (3) risk adjustment of analysis using expected value concepts, and (4) mutually exclusive alternative analysis and service producing alternatives. Case study analysis of a mineral or petroleum investment situation is required. Students may not take EBGN504 for credit if they have completed EBGN321.

EBGN509. MATHEMATICAL ECONOMICS. 3.0 Semester Hrs.
This course reviews and re-enforces the mathematical and computer tools that are necessary to earn a graduate degree in Mineral Economics. It includes topics from differential and integral calculus; probability and statistics; algebra and matrix algebra; difference equations; and linear, mathematical and dynamic programming. It shows how these tools are applied in an economic and business context with applications taken from the mineral and energy industries. It requires both analytical as well as computer solutions. At the end of the course you will be able to appreciate and apply mathematics for better personal, economic and business decision making. Prerequisites: Principles of Microeconomics, and MATH111.

EBGN510. NATURAL RESOURCE ECONOMICS. 3.0 Semester Hrs.
The threat and theory of resource exhaustion; commodity analysis and the problem of mineral market instability; cartels and the nature of mineral pricing; the environment; government involvement; mineral policy issues; and international mineral trade. This course is designed for entering students in mineral economics. Prerequisite: Principles of Microeconomics.

EBGN511. MICROECONOMICS. 3.0 Semester Hrs.
(I, II, S) This is a graduate course dealing with applied microeconomic theory. The course concentrates on the behavior of individual segments of the economy, the theory of consumer behavior and demand, duality, welfare measures, policy instruments, preferences over time and states of nature, and the fundamentals of game theory. Prerequisites: MATH111, EBGN509. 3 hours lecture; 3 semester hours.

EBGN512. MACROECONOMICS. 3.0 Semester Hrs.
This course will provide an introduction to contemporary macroeconomic concepts and analysis. Macroeconomics is the study of the behavior of the economy as an aggregate. Topics include the equilibrium level of inflation, interest rates, unemployment and the growth in national income. The impact of government fiscal and monetary policy on these variables and the business cycle, with particular attention to the effects on the mineral industry. Prerequisites: Principles of Microeconomics, MATH111.

EBGN515. ECONOMICS AND DECISION MAKING. 3.0 Semester Hrs.
The application of microeconomic theory to business strategy. Understanding the horizontal, vertical, and product boundaries of the modern firm. A framework for analyzing the nature and extent of competition in a firm's dynamic business environment. Developing strategies for creating and sustaining competitive advantage.

EBGN521. MICROECONOMICS OF MINERAL AND ENERGY MARKETS. 3.0 Semester Hrs.
(I) This is a graduate course dealing with applied microeconomic theory. This course concentrates on the behavior of the minerals and energy segment of the economy, the theory of production and cost, the theory of consumer behavior and demand, derived demand, price and output level determination by firms, and the competitive structure of product and input markets. Prerequisites: MATH111, EBGN509. 3 hours lecture; 3 semester hours.

EBGN523. MINERAL AND ENERGY POLICY. 3.0 Semester Hrs.
(II) An analysis of current topics in the news in mineral and energy issues through the lens of economics. Since many of the topics involve government policy, the course provides instruction related to the economic foundations of mineral and energy policy analysis. 3 credit hours.

EBGN525. BUSINESS ANALYTICS. 3.0 Semester Hrs.
(I) This introductory course provides an analytic approach to problems that arise in business. Evaluating alternative courses of action in today's competitive business environment requires the extensive use of data based analytic methods. This course covers deterministic optimization models such as linear programming, non-linear programming, integer programming, and network modeling and an introduction to probability models and linear regression. Applications of the models are covered using spreadsheets. The intent of the course is to enhance analytic modeling abilities and to develop quantitative managerial and spreadsheet skills to support and improve decision making. The models cover applications in the areas of earth, energy, production, logistics, work force scheduling, marketing and finance. 3 hours lecture; 3 semester hours.

EBGN526. STOCHASTIC MODELS IN MANAGEMENT SCIENCE. 3.0 Semester Hrs.
(II) This course introduces the tools of stochastic modeling that are very useful in solving analytical problems in business. We cover methodologies that help to quantify the dynamic relationships of sequences of random events that evolve over time. Topics include static and dynamic Monte-Carlo simulation, discrete and continuous time Markov chains, probabilistic dynamic programming, Markov decision processes, queuing processes and networks, Brownian motion and stochastic control. Applications from a wide range of fields will be introduced including marketing, finance, production, logistics and distribution, energy and service systems. In addition to an intuitive understanding of analytical techniques to model stochastic processes, the course emphasizes how to use related software packages for managerial decision-making. 3 hours lecture; 3 semester hours.

EBGN528. INDUSTRIAL SYSTEMS SIMULATION. 3.0 Semester Hrs.
The course focuses on creating computerized models of real or proposed complex systems for performance evaluation. Simulation provides a cost effective way of pre-testing proposed systems and answering ?what-if? questions before incurring the expense of actual implementations. The course is instructed in the state-of-the-art computer lab (CTLM), where each student is equipped with a personal computer and interacts with the instructor during the lecture. Professional version of a widely used commercial software package, ?Arena?, is used to build models, analyze and interpret the results. Other business analysis and productivity tools that enhance the analysis capabilities of the simulation software are introduced to show how to search for optimal solutions within the simulation models. Both discrete-event and continuous simulation models are covered through extensive use of applications including call centers, various manufacturing operations, production/inventory systems, bulk-material handling and mining, port operations, high-way traffic systems and computer networks. Prerequisites: MATH111, MATH530.

EBGN530. ECONOMICS OF INTERNATIONAL ENERGY MARKETS. 3.0 Semester Hrs.
Application of models to understand markets for oil, gas, coal, electricity, and renewable energy resources. Models, modeling techniques, and issues included are supply and demand, market structure, transportation models, game theory, futures markets, environmental issues, energy policy, energy regulation, input/output models, energy conservation, and dynamic optimization. The emphasis in the course is on the development of appropriate models and their application to current issues in energy markets. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN510, EBGN511.

EBGN535. ECONOMICS OF METAL INDUSTRIES AND MARKETS. 3.0 Semester Hrs.
(I, II, S) Metal supply from main product, byproduct, and secondary production. Metal demand and intensity of use analysis. Market organization and price formation. Public policy, comparative advantage, and international metal trade. Metals and economic development in the developing countries and former centrally planned economies. Environmental policy and mining and mineral processing. Students prepare and present a major research paper. Prerequisites: EBGN201, MATH111, EBGN509, and EBGN510. 3 hours lecture; 3 semester hours.

EBGN536. MINERAL POLICIES AND INTERNATIONAL INVESTMENT. 3.0 Semester Hrs.
Identification and evaluation of international mineral investment policies and company responses using economic, business and legal concepts. Assessment of policy issues in light of stakeholder interests and needs. Theoretical issues are introduced and then applied to case studies, policy drafting, and negotiation exercises to assure both conceptual and practical understanding of the issues. Special attention is given to the formation of national policies and corporate decision making concerning fiscal regimes, project financing, environmental protection, land use and local community concerns and the content of exploration and extraction agreements. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN510, EBGN511.

EBGN540. ACCOUNTING AND FINANCE. 3.0 Semester Hrs.
(I) Included are the relevant theories associated with capital budgeting, financing decisions, and dividend policy. This course provides an in-depth study of the theory and practice of corporate accounting and financial management including a study of the firm's objectives, investment decisions, long-term financing decisions, and working capital management. Preparation and interpretation of financial statements and the use of this financial information in evaluation and control of the organization. 3 hours lecture; 3 semester hours.

EBGN541. INTERNATIONAL TRADE. 3.0 Semester Hrs.
Theories and evidence on international trade and development. Determinants of static and dynamic comparative advantage. The arguments for and against free trade. Economic development in nonindustrialized countries. Sectoral development policies and industrialization. The special problems and opportunities created by extensive mineral resource endowments. The impact of value-added processing and export diversification on development. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN511.

EBGN542. ECONOMIC DEVELOPMENT. 3.0 Semester Hrs.
Role of energy and minerals in the development process. Sectoral policies and their links with macroeconomic policies. Special attention to issues of revenue stabilization, resource largesse effects, downstream processing, and diversification. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN511, EBGN512.

EBGN546. INVESTMENT AND PORTFOLIO MANAGEMENT. 3.0 Semester Hrs.
This course covers institutional information, valuation theory and empirical analysis of alternative financial investments, including stocks, bonds, mutual funds, ETS, and (to a limited extent) derivative securities. Special attention is paid to the role of commodities (esp. metals and energy products) as an alternative investment class. After an overview of time value of money and arbitrage and their application to the valuation of stocks and bonds, there is extensive treatment of optimal portfolio selection for risk averse investors, mean-variance efficient portfolio theory, index models, and equilibrium theories of asset pricing including the capital asset pricing model (CAPM) and arbitrage pricing theory (APT). Market efficiency is discussed, as are its implications for passive and active approaches to investment management. Investment management functions and policies, and portfolio performance evaluation are also considered. Prerequisites: Principles of Microeconomics, MATH111, MATH530.

EBGN547. FINANCIAL RISK MANAGEMENT. 3.0 Semester Hrs.
Analysis of the sources, causes and effects of risks associated with holding, operating and managing assets by individuals and organizations; evaluation of the need and importance of managing these risks; and discussion of the methods employed and the instruments utilized to achieve risk shifting objectives. The course concentrates on the use of derivative assets in the risk management process. These derivatives include futures, options, swaps, swaptions, caps, collars and floors. Exposure to market and credit risks will be explored and ways of handling them will be reviewed and critiqued through analysis of case studies from the mineral and energy industries. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBGN505; EBGN545 or EBGN546. Recommended: EBGN509, EBGN511.

EBGN553. PROJECT MANAGEMENT. 3.0 Semester Hrs.
(I, II) 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. Prerequisites: Enrollment in the M.S. in Engineering and Technology Management (ETM) Program. 3 hours lecture; 3 semester hours.

EBGN555. 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 and stochastic programming 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: MATH111; MATH332 or EBGN509. 3 hours lecture; 3 semester hours.

EBGN559. SUPPLY CHAIN MANAGEMENT. 3.0 Semester Hrs.
The focus of the course is to show how a firm can achieve better ?supply-demand matching? through the implementation of rigorous mathematical models and various operational/tactical strategies. We look at organizations as entities that must match the supply of what they produce with the demand for their products. A considerable portion of the course is devoted to mathematical models that treat uncertainty in the supply-chain. 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? may be introduced, such as reverse logistics issues in the supply-chain or contemporary operational and financial hedging strategies, as time permits Prerequisites: MATH111, MATH530.

EBGN560. DECISION ANALYSIS. 3.0 Semester Hrs.
(I) Introduction to the science of decision making and risk theory. Application of decision analysis and utility theory to the analysis of strategic decision problems. Focuses on the application of quantitative methods to business problems characterized by risk and uncertainty. Choice problems such as decisions concerning major capital investments, corporate acquisitions, new product introductions, and choices among alternative technologies are conceptualized and structured using the concepts introduced in this course. 3 hours lecture; 3 semester hours.

EBGN563. MANAGEMENT OF TECHNOLOGY. 3.0 Semester Hrs.
Case studies and reading assignments explore strategies for profiting from technology assets and technological innovation. The roles of strategy, core competencies, product and process development, manufacturing, R&D, marketing, strategic partnerships, alliances, intellectual property, organizational architectures, leadership and politics are explored in the context of technological innovation. The critical role of organizational knowledge and learning in a firm?s ability to leverage technological innovation to gain competitive advantage is explored. The relationships between an innovation, the competencies of the innovating firm, the ease of duplication of the innovation by outsiders, the nature of complementary assets needed to successfully commercialize an innovation and the appropriate strategy for commercializing the innovation are developed. Students explore the role of network effects in commercialization strategies, particularly with respect to standards wars aimed at establishing new dominant designs. Prerequisite: EBGN5043 recommended.

EBGN564. MANAGING NEW PRODUCT DEVELOPMENT. 3.0 Semester Hrs.
Develops interdisciplinary skills required for successful product development in today?s competitive marketplace. Small product development teams step through the new product development process in detail, learning about available tools and techniques to execute each process step along the way. Each student brings his or her individual disciplinary perspective to the team effort, and must learn to synthesize that perspective with those of the other students in the group to develop a sound, marketable product. Prerequisite: EBGN563 recommended.

EBGN565. MARKETING FOR TECHNOLOGY-BASED COMPANIES. 3.0 Semester Hrs.
This class explores concepts and practices related to marketing in this unique, fast-paced environment, including the defining characteristics of high-technology industries; different types and patterns of innovations and their marketing implications; the need for (and difficulties in) adopting a customer-orientation; tools used to gather marketing research/intelligence in technology-driven industries; use of strategic alliances and partnerships in marketing technology; adaptations to the "4 P's"; regulatory and ethical considerations in technological arenas. Prerequisite: None.

EBGN566. TECHNOLOGY ENTREPRENEURSHIP. 3.0 Semester Hrs.
Introduces concepts related to starting and expanding a technological-based corporation. Presents ideas such as developing a business and financing plan, role of intellectual property, and the importance of a good R&D program. Prerequisite: None.

EBGN567. BUSINESS LAW AND ETHICS. 3.0 Semester Hrs.
(I) This course incorporates a broad range of legal topics and ethical issues relevant to technology-based organizations, from start-ups to mature Fortune 100 international corporations. The topics encompass numerous aspects of U.S. business law, including but not limited to: the U.S. court system, contracts, e-commerce, managerial ethics, white collar crimes, early stage business formation, intellectual property, product liability, agency law, employment law, mergers and acquisitions, antitrust, and unfair competition law. The course is discussion based, with some lecture, and is 3 semester credit hours. There are no prerequisites required for this course. A significant portion of class time will be applied to exploring and discussing assigned topics through relevant abbreviated court case descriptions, ethics reader assignments and current and recent events in global business. He overall goal of this course is not to make students legal experts but to make them better managers and leaders by equipping them with relevant legal. 3 hours lecture; 3 semester hours.

EBGN568. ADVANCED PROJECT ANALYSIS. 3.0 Semester Hrs.
An advanced course in economic analysis that will look at more complex issues associated with valuing investments and projects. Discussion will focus on development and application of concepts in after-tax environments and look at other criteria and their impact in the decision-making and valuation process. Applications to engineering and technology aspects will be discussed. Effective presentation of results will be an important component of the course. Prerequisite: EBGN504.

EBGN570. ENVIRONMENTAL ECONOMICS. 3.0 Semester Hrs.
The role of markets and other economic considerations in controlling pollution; the effect of environmental policy on resource allocation incentives; the use of benefit/cost analysis in environmental policy decisions and the associated problems with measuring benefits and costs. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN510.

EBGN571. MARKETING ANALYTICS. 3.0 Semester Hrs.

(II) The purpose of this course is to gain an understanding of how data about customers and markets can be used to support and improve decision making. Using market data to evaluate alternatives and gain insight from past performance is the essence of marketing analytics. The course is focused on the marketing research decisions facing product managers in technology based companies and will appeal to students who want to gain a deeper understanding of such topics as the problems of target market selection, new product introductions, pricing, and customer retention. While the specifics of market analytics can vary across industries and firms, three main commonalities are: (1) defining the decision problem, (2) collection and analysis of high quality market data, and (3) implementing strategy through marketing mix decisions. In this course students will develop an understanding of available marketing analytic methods and the ability to use marketing research information to make strategic and tactical decisions. 3 hours lecture; 3 semester hours.

EBGN572. INTERNATIONAL BUSINESS STRATEGY. 3.0 Semester Hrs.

The purpose of this course is to gain understanding of the complexities presented by managing businesses in an international environment. International business has grown rapidly in recent decades due to technological expansion, liberalization of government policies on trade and resource movements, development of institutions needed to support and facilitate international transactions, and increased global competition. Due to these factors, foreign countries increasingly are a source of both production and sales for domestic companies. Prerequisite: None.

EBGN573. ENTREPRENEURIAL FINANCE. 3.0 Semester Hrs.

Entrepreneurial activity has been a potent source of innovation and job generation in the global economy. In the U.S., the majority of new jobs are generated by new entrepreneurial firms. The financial issues confronting entrepreneurial firms are drastically different from those of established companies. The focus in this course will be on analyzing the unique financial issues which face entrepreneurial firms and to develop a set of skills that has wide applications for such situations. Prerequisite: EBGN505. Corequisite: EBGN545.

EBGN575. ADVANCED MINING AND ENERGY ASSET VALUATION. 3.0 Semester Hrs.

(I) The use of option pricing techniques in mineral and energy asset valuation. Mining and energy valuation standards and guidelines. Differentiation between static decision making, intertemporal decision making, and dynamic decision making under uncertainty. The comparison sales and cost approaches to valuation. Commodity price simulation and price forecasting. Risk-neutral valuation. Prerequisites: EBGN504, EBGN509, EBGN510, EBGN511, EBGN521, EBGN590. 3 hours lecture; 3 semester hours.

EBGN576. MANAGING AND MARKETING NEW PRODUCT DEVELOPMENTS. 3.0 Semester Hrs.

(II) This course provides a scientific approach to developing and marketing new products which are often critical to the success of firms competing in technology based industries. We will start with an overview of core marketing and then develop prototypes of a new product design. We will step through the new product development process in detail, learning about available tools and techniques to execute each process step along the way. New product prototypes will be used to gather data from prospective target markets and assess the viability of the design in the marketplace. 3 hours lecture; 3 semester hours.

EBGN580. EXPLORATION ECONOMICS. 3.0 Semester Hrs.

Exploration planning and decision making for oil and gas, and metallic minerals. Risk analysis. Historical trends in exploration activity and productivity. Prerequisites: Principles of Microeconomics, EBGN510. Offered when student demand is sufficient.

EBGN585. ENGINEERING AND TECHNOLOGY MANAGEMENT CAPSTONE. 3.0 Semester Hrs.

This course represents the culmination of the ETM Program. This course is about the strategic management process ? how strategies are developed and imple mented in organizations. It examines senior management?s role in formulating strategy and the role that all an organization?s managers play in implementing a well thought out strategy. Among the topics discussed in this course are (1) how different industry conditions support different types of strategies; (2) how industry conditions change and the implication of those changes for strategic management; and (3) how organizations develop and maintain capabilities that lead to sustained competitive advantage. This course consists of learning fundamental concepts associated with strategic management process and competing in a web-based strategic management simulation to support the knowledge that you have developed. Prerequisites: MATH530, EBGN504.

EBGN590. ECONOMETRICS I. 3.0 Semester Hrs.

(II) This course covers the statistical methods used by economists to estimate economic relationships and empirically test economic theories. Topics covered include hypothesis testing, ordinary least squares, specification error, serial correlations, heteroskedasticity, qualitative and limited dependent variables, time series analysis and panel data. Prerequisites: MATH111, MATH530, EBGN509. 3 hours lecture and discussion; 3 semester hours.

EBGN594. TIME-SERIES ECONOMETRICS. 3.0 Semester Hrs.

(II) This is a course in applied time-series econometrics. It covers contemporary approaches for interpreting and analyzing time-series economic data. Hypothesis testing and forecasting both receive attention. Topics include stochastic difference equations, applied forecasting, stationary univariate models, models with constant and time-varying variance, deterministic and stochastic trend models and associated unit root and structural break tests, as well as single-equation and multiple-equation time-series models that include error-correction techniques and cointegration tests. 3 hours lecture; 3 semester hours.

EBGN598. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EBGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EBGN610. ADVANCED NATURAL RESOURCE ECONOMICS. 3.0 Semester Hrs.
Optimal resource use in a dynamic context using mathematical programming, optimal control theory and game theory. Constrained optimization techniques are used to evaluate the impact of capital constraints, exploration activity and environmental regulations. Offered when student demand is sufficient. Prerequisites: Principles of Microeconomics, MATH111, MATH5301, EBGN509, EBGN510, EBGN511.

EBGN611. ADVANCED MICROECONOMICS. 3.0 Semester Hrs.
A second graduate course in microeconomics, emphasizing state-of-the-art theoretical and mathematical developments. Topics include consumer theory, production theory and the use of game theoretic and dynamic optimization tools. Prerequisites: Principles of Microeconomics, MATH111, MATH5301, EBGN509, EBGN511.

EBGN632. PRIMARY FUELS. 3.0 Semester Hrs.
(II) Application of models to understand markets for oil, gas, coal exploration and extraction. Empirical, theoretical and quantitative models and modeling techniques are stressed. The issues included are identification of cause and effect, market structure, game theory, futures markets, environmental issues, energy policy, energy regulation. The emphasis in the course is on the development of appropriate models and their application to current issues in primary fuel/upstream markets. Prerequisites: EBGN590. 3 hours lecture; 3 semester hours.

EBGN645. COMPUTATIONAL ECONOMICS. 3.0 Semester Hrs.
(II) This course is about learning the skills required to construct and manipulate numerical models as an instrument of economic research. In the first part of the course, students will learn about basic classes of optimization problems as ways to operationalize models of equilibrium behavior from economics and how to formulate and solve these problems on the computer. In the second part of the course, students will focus on the techniques used specifically in computable general equilibrium (CGE) analysis and developing applications of CGE models to topics in energy, environmental and natural resource economics. Prerequisites: MATH111, MATH530, Principles of Microeconomics, EBGN509, EBGN511. 3 hours lecture; 3 semester hours.

EBGN655. ADVANCED LINEAR PROGRAMMING. 3.0 Semester Hrs.
Equivalent with EBGN650,
As an advanced course in optimization, this course will expand upon topics in linear programming. Specific topics to be covered include advanced formulation, column generation, interior point method, stochastic optimization, and numerical stability in linear programming. Applications of state-of-the-art hardware and software will emphasize solving real-world problems in areas such as mining, energy, transportation and the military. Prerequisites: EBGN555. 3 hours lecture; 3 semester hours.

EBGN690. ECONOMETRICS II. 3.0 Semester Hrs.
A second course in econometrics. Compared to EBGN590, this course provides a more theoretical and mathematical understanding of econometrics. Matrix algebra is used and model construction and hypothesis testing are emphasized rather than forecasting. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBGN509, EBGN590. Recommended: EBGN511.

EBGN695. RESEARCH METHODOLOGY. 3.0 Semester Hrs.
Lectures provide an overview of methods used in economic research relating to EPP and QBA/OR dissertations in Mineral Economics and information on how to carry out research and present research results. Students will be required to write and present a research paper that will be submitted for publication. It is expected that this paper will lead to a Ph.D. dissertation proposal. It is a good idea for students to start thinking about potential dissertation topic areas as they study for their qualifier. This course is also recommended for students writing Master?s thesis or who want guidance in doing independent research relating to the economics and business aspects of energy, minerals and related environmental and technological topics. Prerequisites: MATH530, EBGN509, EBGN510, EBGN511, EBGN590.

EBGN698. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EBGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EBGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Geology and Geological Engineering

Degrees Offered

- Master of Science (Geology)
- Master of Science (Geological Engineering)
- Doctor of Philosophy (Geology)
- Doctor of Philosophy (Geological Engineering)
- Master of Engineering (Geological Engineer) (Non-Thesis)
- Professional Master Degree (Petroleum Reservoir Systems) (Non-Thesis)
- Professional Master Degree (Mineral Exploration) (Non-Thesis)

Program Description

The Department of Geology and Geological Engineering offers Master of Science and Doctor of Philosophy degrees in Geology; and Master of Engineering, and Master of Science and Doctor of Philosophy degrees in Geological Engineering. Professional Master Degrees are offered in Petroleum Reservoir Systems and Mineral Exploration. Geological Engineering degrees require possession or acquisition of an undergraduate engineering degree or its equivalent.

Graduate students desiring to study ground water, engineering geology/ geotechnics, mining engineering geology and some environmental applications are generally expected to pursue the Geological Engineering degree. Students desiring to study petroleum or minerals exploration or development sciences, and/or geology generally pursue Geology degrees. Students are initially admitted to either geoscience or geological engineering degree programs and must receive approval of the GE department Graduate Advisory Committee to switch degree category.

Geoscience students may also choose among several interdisciplinary graduate programs comprised of faculty from several different CSM departments. The most common choices are Geochemistry, Hydrologic Science and Engineering, and Underground Construction and Tunneling. Please see sections in the Catalog for each of these programs.

Program Requirements

Geology Degrees

The Master of Science (Geology) program will require 36 semester hours of course and research credit hours (a maximum of 9 credit hours may be 400-level course work). Twelve of the 36 credit hours must be research credits. To ensure breadth of background, the course of study for the Master of Science (Geology) degree must include at least one graduate course in each of the fields of stratigraphy/ sedimentology, structural geology/tectonics, and petrology. At the discretion of the student's Thesis Advisory Committee, an appropriate course may be substituted for one (and only one) of the fields above. All Master of Science (Geology) candidates must also complete an appropriate thesis, based upon original research they have conducted. A thesis proposal and course of study must be approved by the student's Thesis Advisory Committee before the candidate begins substantial work on the thesis research.

The requirement for **Doctor of Philosophy (Geology)** program will be established individually by a student's Doctoral Thesis Advisory Committee, but must meet the minimum requirements presented below. The Doctor of Philosophy (Geology) academic program requires a minimum of 72 credit hours beyond the Bachelor degree (a maximum of 9 credit hours may be 400-level course work), with a minimum of 36.0 course credit hours.

Students who enter the PhD program with a thesis-based Master's degree may transfer up to 36 semester hours in recognition of the course work and research completed for that degree. At the discretion of the student's Doctoral Thesis Advisory Committee, up to 24 semester hours of previous graduate-level course work (at CSM or elsewhere) can be applied towards the course requirement of the Doctor of Philosophy (Geology). Students who have previously earned a thesis-based Master's degree will typically take a minimum of 6 course credits and 6 research credits each of the first two semesters of their residence.

Each entering student will select an appropriate Doctoral Thesis Advisory Committee who will decide if any deficiency coursework is necessary and establish the course of study. All Doctor of Philosophy (Geology) students must pass a qualifying examination, which is expected to be conducted immediately following the semester in which the required 36 course credit hours have been completed. The examination will be administered by the student's Thesis Advisory Committee and will consist of a written and an oral part. Depending on the outcome of the qualifying examination, the Doctoral Thesis Advisory Committee can recommend students to take up to 6 additional course credits. In the case of failure of the comprehensive examination, a re-examination may be given upon the recommendation of the Thesis Advisory Committee and the thesis advisor. Students must prepare and defend a thesis proposal that must be approved by the student's Doctoral Thesis Advisory Committee before the student begins substantial work on the thesis research. Students must also complete and defend an appropriate thesis based upon original research they have conducted and are encouraged to have submitted at least two manuscripts based on the dissertation work for publication in peer-reviewed scholarly journals before defending their thesis.

Prospective students should submit the results of the Graduate Record Examination with their application for admission to graduate study. In the event that it is not possible, because of geographic and other restrictions, to take the Graduate Record Examination prior to enrolling at Colorado School of Mines, enrollment may be granted on a provisional basis subject to satisfactory completion of the examination within the first year of residence.

Prerequisites

Geology Program

The candidate for the degree of Master of Science (Geology) or Doctor of Philosophy (Geology) must have completed the following or equivalent subjects, for which credit toward an advanced degree will not be granted.

- General Geology
- Structural Geology
- Field Geology (6 weeks)
- Mineralogy
- Petrology
- Stratigraphy
- Chemistry (3 semesters, including at least 1 semester of physical or organic)
- Mathematics (2 semesters of calculus)
- An additional science course (other than geology) or advanced mathematics

- Physics (2 semesters)

Professional Master Degree Programs:

Candidates for the Professional Master Degree must possess an appropriate geosciences undergraduate degree or its equivalent. Prerequisites are the same as those required for the Master of Science (Geology) Degree.

Engineering Programs

The candidate for the degree of Master of Engineering (Geological Engineer), Master of Science (Geological Engineering) or Doctor of Philosophy (Geological Engineering) must have completed the following or equivalent subjects. Graduate credit may be granted for courses at or above the 400 level, if approved by the student's advisory committee.

Mathematics

Four semesters including: Calculus (2 semesters) and one semester of any two of: calculus III, differential equations, probability and statistics, numerical analysis, linear algebra, operations research, optimization.

Basic Science

- Chemistry (2 semesters)
- Mineralogy and Petrology
- Physics (2 semesters)
- Stratigraphy or Sedimentation
- Physical Geology
- Computer Programming or GIS

Engineering Science

- Structural Geology and one semester in four of the following subjects:
  - Physical Chemistry or Thermodynamics
  - Statics
  - Mechanics of Materials
  - Fluid Mechanics
  - Dynamics
  - Soil Mechanics
  - Rock Mechanics

Engineering Design

- Field Geology

As part of the graduate program each student must take one semester in two of the following subjects if such courses were not taken for a previous degree:

- Mineral Deposits/Economic Geology
- Hydrogeology
- Engineering Geology

and also as part of the graduate program one semester in three of the following subjects if such courses were not taken for a previous degree:

- Foundation Engineering
- Engineering Hydrology
- Geomorphology
- Airphoto Interpretation, Photogeology, or Remote Sensing
- Petroleum Geology
- Introduction to Mining
- Introductory Geophysics
- Engineering Geology Design
- Mineral Exploration Design
- Groundwater Engineering Design
- Other engineering design courses as approved by the program committee

Professional Master in Mineral Exploration

This non-thesis, master degree program is designed for working professionals who want to increase their knowledge and skills, while gaining a thorough up-date of advances across the spectrum of economic geology, mineral exploration techniques, and mining geosciences. Admission to the program is competitive. Preference will be given to applicants with a minimum of two years of industrial or equivalent experience.

The program requires a minimum of 30 credit hours. A minimum of 15 credit hours must be accumulated in five of the following core areas:

- mineral deposits,
- mineral exploration,
- applied geophysics,
- applied geochemistry,
- applied structural geology,
- petrology,
- field geology, and
- economic evaluation.

An additional 15 credit hours may be selected from the course offerings of the Department of Geology and Geological Engineering and allied departments including Mining Engineering, Economics and Business, Geophysics, Chemistry and Geochemistry, Metallurgy and Materials Science, and Environmental Sciences.

Selection of courses will be undertaken in consultation with the academic advisor. Up to 9 credit hours may be at the 400-level. All other credits towards the degree must be 500-level or above. A maximum of 9 credit hours may be independent study focusing on a topic relevant to the mineral exploration and mining industries.

Prerequisites: Admission to the program is generally restricted to individuals holding a four-year undergraduate degree in earth sciences. Candidates for the degree of Professional Master in Mineral Exploration must have completed the following or equivalent subjects, for which credit toward the advanced degree will not be granted. These are general geology, structural geology, field geology, mineralogy, petrology, chemistry (2 semesters), mathematics (2 semesters of calculus), physics (1 semester), and an additional science course other than geology.

Professional Master in Petroleum Reservoir Systems

This is a non-thesis, interdisciplinary master degree program jointly administered by the departments of Geology and Geological Engineering, Geophysics, and Petroleum Engineering. This program consists only of coursework in petroleum geoscience and engineering. No research is required.

General Administration

The three participating departments share oversight for this program through a committee consisting of one faculty member from each of the three departments. Students gain admission to the program by application to any of the three sponsoring departments. Students are administered by that department into which they first matriculate.

Requirements

The program requires a minimum of 36 credit hours. Up to 9 credit hours may be at the 400 level. All other credits toward the degree must be 500 level or above.

9-10 hours must consist of:

One course selected from the following:		
GEGN438	PETROLEUM GEOLOGY	4.0
GPGN419	INTRODUCTION TO FORMATION EVALUATION AND WELL LOGGING	3.0
or PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	
Two courses selected from the following:		
GEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	3.0
or GPGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
or PEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
GEGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	3.0
or GPGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	
or PEGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	
GEOL609	ADVANCED PETROLEUM GEOLOGY	3.0

9 additional hours must consist of one course each from the 3 participating departments.

The remaining 18 hours may consist of graduate courses from any of the 3 participating departments, or other courses approved by the committee. Up to 6 hours may consist of independent study, including an industry project.

Geological Engineering Degrees

The Master of Engineering (Non-Thesis) Program in Geological Engineering outlined below may be completed by individuals already holding undergraduate or advanced degrees or as a **combined degree program** (see Graduate Degrees and Requirements (p. 7) section of this bulletin) by individuals already matriculated as undergraduate students at The Colorado School of Mines. The program is comprised of:

CORE	Course Work	30.0
GEGN599	INDEPENDENT STUDY	6.0
Total Semester Hrs		36.0

Up to nine credit hours can be at the 400 level and the remainder will be 500 or 600 level. For the combined degree program, courses recommended as appropriate for double counting may be chosen from:

GEGN403	MINERAL EXPLORATION DESIGN	3.0
GEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	3.0
GEGN469	ENGINEERING GEOLOGY DESIGN	3.0
GEGN470	GROUND-WATER ENGINEERING DESIGN	3.0

The typical program plan includes 15 course credit hours in both the fall and the spring terms followed by 6 independent study credit hours during the summer term. The non-thesis degree includes three areas of specialization (engineering geology/geotechnics, ground-water engineering, and mining geological engineering).

All Master of Engineering (Non-Thesis) program will include the following core requirements:

GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN599	INDEPENDENT STUDY	6.0

GEGN599 requires a project and report that demonstrate competence in the application of geological engineering principles that merits a grade of B or better. The project topic and content of the report is determined by the student's advisor, in consultation with the student, and is approved by the Geological Engineering Graduate Program Committee. The format of the report will follow the guidelines for a professional journal paper.

The student, in consultation with the advisor, must prepare a formal program of courses and independent study topic for approval by the Geological Engineering Graduate Program Committee. The program must be submitted to the committee on or before the end of the first week of classes of the first semester.

The most common difficulty in scheduling completion of the degree involves satisfaction of prerequisites. Common deficiency courses are Statics, Mechanics of Materials, and Fluid Mechanics. These are essential to the engineering underpinnings of the degree. An intense program at CSM involving 18 credit hours each semester including Statics in the fall and Fluid Mechanics in the spring and 9 credits in the summer including Mechanics of Materials, allows these classes to be taken along with the standard program. Some students may choose to take these prerequisites elsewhere before arriving on the CSM campus.

Engineering Geology/Geotechnics Specialty (Non-Thesis)

Students working towards a Masters of Engineering (non-thesis) with specialization in Engineering Geology/ Geotechnics must meet the prerequisite course requirements listed later in this section. Required courses for the degree are:

GEGN467	GROUNDWATER ENGINEERING	4.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN570	CASE HISTORIES IN GEOLOGICAL ENGINEERING AND HYDROGEOLOGY	3.0
or GEGN571	ADVANCED ENGINEERING GEOLOGY	
GEGN573	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN599	INDEPENDENT STUDY	6.0
GEGN671	LANDSLIDES: INVESTIGATION, ANALYSIS & MITIGATION	3.0
or GEGN672	ADVANCED GEOTECHNICS	
GE ELECT	Electives *	10.0
Total Semester Hrs		36.0

* Electives and course substitutions are approved by the Geological Engineering Graduate Program Committee and must be consistent with the program specialization. As part of their elective courses, students are required to have an advanced course in both soil and rock engineering. Possibilities for other electives include graduate-level rock mechanics and rock engineering, soil mechanics and foundations, ground water, site characterization, geographical information systems (GIS), project management and geophysics, for example.

Ground Water Engineering/Hydrogeology Specialty (Non-Thesis)

Students working towards a Masters of Engineering (non-thesis) with specialization in Ground Water Engineering and Hydrogeology must meet the prerequisite course requirements listed later in this section. Required courses for the degree (36 hours) are:

GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN532	GEOLOGICAL DATA ANALYSIS (Fall)	3.0
GEGN681	VADOSE ZONE HYDROLOGY (Fall)	3.0
or GEGN581	ANALYTICAL HYDROLOGY	
GEGN509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY (Fall or Spring)	3.0
or CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS (Spring)	3.0
GEGN470	GROUND-WATER ENGINEERING DESIGN (Spring)	3.0
or CEEN575	HAZARDOUS WASTE SITE REMEDIATION	
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS (Fall/Spring)	3.0
GEGN599	INDEPENDENT STUDY Summer	6.0
GE ELECT	Electives *	9.0
Total Semester Hrs		36.0

* Electives and course substitutions are approved by the Geological Engineering Graduate Program Committee and must be consistent with the program specialization. As part of their elective courses, students are required to have at least one additional advanced course in hydrogeochemistry. Possibilities for other electives include courses in site characterization, environmental science and engineering, geographical information systems (GIS), geochemistry, and geophysics, for example.

Mining Geological Engineering Specialty (Non-Thesis)

Students working towards a Masters of Engineering (non-thesis) with specialization in Mining Geology must meet the prerequisite course requirements listed later in this section. Required courses for the degree are:

GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
or GEGN467	GROUNDWATER ENGINEERING	
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEOL515	ADVANCED MINERAL DEPOSITS	3.0
Selected Topics		2-4
MNGN523	SELECTED TOPICS (Surface Mine Design OR)	
MNGN523	SELECTED TOPICS (Underground Mine Design)	
GE ELECT	Elective *	3.0
GEOL505	ADVANCED STRUCTURAL GEOLOGY	3.0
GEOL520	NEW DEVELOPMENTS IN THE GEOLOGY AND EXPLORATION OF ORE DEPOSITS	3.0
GE ELECT	Elective *	6.0
GEGN599	INDEPENDENT STUDY	6.0
Total Semester Hrs		33-35

* Electives and course substitutions are approved by the Geological Engineering Graduate Program Committee and must be consistent with the program specialization. Typically, the elective courses are selected from the following topical areas: mineral deposits geology, ore microscopy, applied geophysics, applied geochemistry, remote sensing, engineering geology, environmental geology, engineering economics / management, mineral processing, geostatistics, geographic information systems, environmental or exploration and mining law, and computers sciences.

The **Master of Science Degree Program in Geological Engineering** requires a minimum of 36 semester hours of course and project/research credit hours (a maximum of 9 credit hours may be 400-level course work), plus a Graduate Thesis. The degree includes three areas of specialization (engineering geology/geotechnics, groundwater engineering, and mining geological engineering) with common requirements as follows:

GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN707	GRADUATE THESIS/DISSERTATION RESEARCH CREDIT (minimum)	12.0
GEGN	Course work, approved by the thesis committee	24.0
Total Semester Hrs		39.0

The content of the thesis is to be determined by the student's advisory committee in consultation with the student. The Masters thesis must demonstrate creative and comprehensive ability in the development or application of geological engineering principles. The format of the thesis will follow the guidelines described under the Thesis Writer's Guide.

In addition to the common course requirements, the Master of Science degree with **specialization in Engineering Geology/Geotechnics** requires:

GEGN467	GROUNDWATER ENGINEERING	4.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN570	CASE HISTORIES IN GEOLOGICAL ENGINEERING AND HYDROGEOLOGY	3.0
Select at least two of the following:		6.0
GEGN571	ADVANCED ENGINEERING GEOLOGY	
GEGN573	GEOLOGICAL ENGINEERING SITE INVESTIGATION	
GEGN671	LANDSLIDES: INVESTIGATION, ANALYSIS & MITIGATION	
GEGN672	ADVANCED GEOTECHNICS	
Total Semester Hrs		17.0

Typically, the additional courses are selected from the following topical areas: engineering geology, groundwater engineering, groundwater modeling, soil mechanics and foundations, rock mechanics, underground construction, seismic hazards, geomorphology, geographic information systems, construction management, finite element modeling, waste management, environmental engineering, environmental law, engineering management, and computer programming.

In addition to the common course requirements, the Master of Science degree with specialization in Ground Water also requires the following courses:

GEGN467	GROUNDWATER ENGINEERING	4.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
2 Courses Selected as Follows:		6.0
CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	
CEEN580	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	
GEGN509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	
GEGN581	ANALYTICAL HYDROLOGY	
Total Semester Hrs		17.0

As nearly all ground water software is written in Fortran, if the student does not know Fortran, a Fortran course must be taken before graduation, knowledge of other computer languages is encouraged.

In addition to the common course requirements, the Master of Science degree with **specialization in Mining Geology** also requires:

Specialty Areas (minimum)	17.0
Total Semester Hrs	17.0

This will include about 5–6 courses (predominantly at 500 and 600 level) selected by the student in conjunction with the Masters program advisory committee. Specialty areas might include: mineral deposits geology, mineral exploration, mining geology, mineral processing, applied geophysics, applied geochemistry, engineering geology, environmental geology, geostatistics, geographic information systems, environmental or exploration and mining law, engineering economics/ management, and computer sciences.

The **Doctor of Philosophy (Geological Engineering)** degree requires a minimum of 72 hours course work and research combined. Requirements include the same courses as for the Master of Science (Geological Engineering) with the additions noted below. After completing all coursework and an admission to candidacy application, the Dissertation is completed under GEGN707 Graduate Research. The content of the dissertation is to be determined by the student's advisory committee in consultation with the student. The dissertation must make a new contribution to the geological engineering profession. The format of the dissertation will follow the guidelines described under the Thesis Writer's Guide. A minimum of 24 research credits must be taken. Up to 24 course credit hours may be awarded by the candidate's Doctoral Thesis Advisory Committee for completion of a Master of Science degree (at CSM or elsewhere).

In addition to the common course requirements, a PhD **specializing in Engineering Geology/Geotechnics** requires additional course work tailored to the student's specific interests and approved by the doctoral program committee. (Typically, the additional courses are selected from the following topical areas: engineering geology, groundwater engineering, groundwater modeling, soil mechanics and foundations, rock mechanics, underground construction, seismic hazards, geomorphology, geographic information systems, construction management, finite element modeling, waste management, environmental engineering, environmental law, engineering management, and computer programming.)

In addition to the common course requirements listed previously, a PhD **specializing in Ground Water** also requires:

GEGN581	ANALYTICAL HYDROLOGY	3.0
GEGN669	ADVANCED TOPICS IN ENGINEERING HYDROGEOLOGY	1-2
GEGN681	VADOSE ZONE HYDROLOGY	3.0
GEGN683	ADVANCED GROUND WATER MODELING	3.0

and additional course work tailored to the student's specific interests, which are likely to include chemistry, engineering, environmental science, geophysics, math (particularly Partial Differential Equations), microbiology, organic chemistry, contaminant transport, soil physics, optimization, shallow resistivity or seismic methods. The student's advisory committee has the authority to approve elective courses and any substitutions for required courses.

In addition to the common course requirements, a PhD **specializing in Mining Geology** also requires:

GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
or GEGN467	GROUNDWATER ENGINEERING	
GEOL505	ADVANCED STRUCTURAL GEOLOGY	3.0
GEOL515	ADVANCED MINERAL DEPOSITS	3.0
GEOL520	NEW DEVELOPMENTS IN THE GEOLOGY AND EXPLORATION OF ORE DEPOSITS	3.0
MNGN523	SELECTED TOPICS (Surface Mine Design or Underground Mine Design)	2.0
Total Semester Hrs		15.0

Additional course work suited to the student's specific interests and approved by the doctoral program committee. (Typically, the additional courses are selected from the following topical areas: mineral deposits geology, mineral exploration, mining geology, mineral processing, applied geophysics, applied geochemistry, engineering geology, environmental geology, geostatistics, geographic information systems, environmental or exploration and mining law, engineering economics/management, and computer sciences).

Geochemistry

The Geochemistry Program is an interdisciplinary graduate program administered by the departments of Geology and Geological Engineering and Chemistry and Geochemistry. The geochemistry faculty from each department are responsible for the operations of the program. Student reside in either Department. Please see the Geochemistry section of the Bulletin for detailed information on this degree program.

Hydrologic Science and Engineering

The Hydrologic Science and Engineering (HSE) Program is an interdisciplinary graduate program comprised of faculty from several different CSM departments. Please see the Hydrologic Science and Engineering section of the Bulletin for detailed information on this degree program.

Qualifying Examination

Ph.D. students in Geology, Geological Engineering, Geochemistry, and Hydrologic Science and Engineering must pass a qualifying examination by the end of the second year of their programs. This timing may be adjusted for part-time students. This examination will be administered by the student's Doctoral committee and will consist of an oral and a written examination, administered in a format to be determined by the Doctoral Committee. Two negative votes in the Doctoral Committee constitute failure of the examination. In case of failure of the qualifying examination, a re-examination may be given upon the recommendation of the Doctoral Committee and approval of the Graduate Dean. Only one re-examination may be given.

Professor and Department Head

M. Stephen Enders

Professors

David A. Benson

Wendy J. Harrison

Reed M. Maxwell

Alexei Milkov

Paul M. Santi

Kamini Singha, Associate Department Head

Stephen A. Sonnenberg, Charles Boettcher Distinguished Chair in Petroleum Geology

Richard F. Wendlandt

Lesli J. Wood, Weimer Distinguished Chair and Professor, Geology

Associate Professors

Yvette Kuiper

Thomas Monecke

Piret Plink-Bjorklund

Bruce Trudgill

Wendy Zhou

Assistant Professors

Alexander Gysi

Richard M. Palin

Alexis Sitchler

Gabriel Walton

Teaching Professor

Christian V. Shorey

Research Professors

Marsha French

Richard Goldfarb

Zane Jobe

David Leach

J. Frederick (Rick) Sarg

Research Assistant Professors

Mary Carr

Katharina Pfaff

Professor Emerita

Eileen P. Poeter

Professors Emeriti

John B. Curtis

Thomas L.T. Grose

John D. Haun

Jerry D. Higgins

Murray W. Hitzman

Neil F. Hurley

Keenan Lee

Samuel B. Romberger

A. Keith Turner

John E. Warme

Robert J. Weimer

Associate Professors Emeriti

L. Graham Closs

Timothy A. Cross

Gregory S. Holden

Courses

GEGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.
(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

GEGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

GEGN509. INTRODUCTION TO AQUEOUS GEOCHEMISTRY. 3.0 Semester Hrs.

(I) Analytical, graphical and interpretive methods applied to aqueous systems. Thermodynamic properties of water and aqueous solutions. Calculations and graphical expression of acid-base, redox and solution-mineral equilibria. Effect of temperature and kinetics on natural aqueous systems. Adsorption and ion exchange equilibria between clays and oxide phases. Behavior of trace elements and complexation in aqueous systems. Application of organic geochemistry to natural aqueous systems. Light stable and unstable isotopic studies applied to aqueous systems. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours.

GEGN520. INDUSTRIAL MINERALS AND ROCKS. 3.0 Semester Hrs.

Introduction to the Industrial Minerals industry via appreciation of geologic occurrence, physical and chemical material properties, mining and processing considerations, and marketing of various commodities. Development of skills in preparation of commodity surveys, reserves and resources classifications, and project appraisals. Required field trips to operational sites and trip reports. Mid-term and final exams. Individual student commodity term project and presentation. Prerequisite: Senior or graduate status in earth resources field. 3 hours lecture/seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

GEGN527. ORGANIC GEOCHEMISTRY OF FOSSIL FUELS AND ORE DEPOSITS. 3.0 Semester Hrs.

(II) A study of organic carbonaceous materials in relation to the genesis and modification of fossil fuel and ore deposits. The biological origin of the organic matter will be discussed with emphasis on contributions of microorganisms to the nature of these deposits. Biochemical and thermal changes which convert the organic compounds into petroleum, oil shale, tar sand, coal, and other carbonaceous matter will be studied. Principal analytical techniques used for the characterization of organic matter in the geosphere and for evaluation of oil and gas source potential will be discussed. Laboratory exercises will emphasize source rock evaluation, and oil-source rock and oil-oil correlation methods. Prerequisite: CHGN221, GEGN438. 2 hours lecture; 3 hours lab; 3 semester hours. Offered alternate years.

GEGN530. CLAY CHARACTERIZATION. 2.0 Semester Hrs.

Equivalent with GEOL530,

(I) Clay mineral structure, chemistry and classification, physical properties (flocculation and swelling, cation exchange capacity, surface area and charge), geological occurrence, controls on their stabilities. Principles of X-ray diffraction, including sample preparation techniques, data collection and interpretation, and clay separation and treatment methods. The use of scanning electron microscopy to investigate clay distribution and morphology. Methods of measuring cation exchange capacity and surface area. Prerequisites: GEGN206. 1 hour lecture, 3 hours lab; 2 semester hours.

GEGN532. GEOLOGICAL DATA ANALYSIS. 3.0 Semester Hrs.

(II) Techniques and strategy of data analysis in geology and geological engineering: basic statistics review, analysis of data sequences, mapping, sampling and sample representativity, univariate and multivariate statistics, geostatistics, and geographic information systems (GIS). Practical experience with geological applications via supplied software and data sets from case histories. Prerequisite: MATH323 or MATH530. 3 hours lecture; 3 semester hours.

GEGN561. UNDERGROUND CONSTRUCTION ENGINEERING LABORATORY 1. 0.5 Semester Hrs.

(I) This course provides students with hands-on experience with tools and skills which are commonly used in the underground construction industry. Bi-weekly labs integrate with other courses in the field of Underground Construction and Tunnel Engineering. Co-requisites: CEEN513. 1.5 hours lab; 0.5 semester hours.

GEGN562. UNDERGROUND CONSTRUCTION ENGINEERING LABORATORY 2. 0.5 Semester Hrs.

(II) This course provides students with hands-on experience with tools and skills which are commonly used in the underground construction industry. Bi-weekly labs integrate with other courses in the field of Underground Construction and Tunnel Engineering. Co-requisites: MNGN504 or CEEN523. 1.5 hours lab; 0.5 hours.

GEGN563. APPLIED NUMERICAL MODELLING FOR GEOMECHANICS. 3.0 Semester Hrs.

(I) Course focuses on a comprehensive suite of numerical analysis techniques suited to geotechnical design with a focus on excavations in rock/soil and landslides. Finite element, finite difference, discrete/distinct element and boundary element methods are all discussed with hands-on application workshops using state-of-the-art geomechanics software. Analytical models and pre- and post- processing techniques suited to typical rock engineering problems are developed through assignments. Strength criteria and non-linear inelastic constitutive models for continuum plasticity, brittle fracture and discontinuum deformation are explored in detail. Projects involving real case histories are undertaken to highlight the application of and engineering judgment associated with numerical analysis for problems involving rockmasses. Prerequisites: GEGN468, MNGN321 or CEEN312. 3 hours lecture; 3 semester hours.

GEGN570. CASE HISTORIES IN GEOLOGICAL ENGINEERING AND HYDROGEOLOGY. 3.0 Semester Hrs.

(I) Case histories in geological and geotechnical engineering, ground water, and waste management problems. Students are assigned problems and must recommend solutions and/or prepare defendable work plans. Discussions center on the role of the geological engineer in working with government regulators, private-sector clients, other consultants, and other special interest groups. Prerequisite: GEGN467, GEGN468, GEGN469, GEGN470. 3 hours lecture; 3 semester hours.

GEGN571. ADVANCED ENGINEERING GEOLOGY. 3.0 Semester Hrs.

(I) Emphasis will be on engineering geology mapping methods, and geologic hazards assessment applied to site selection and site assessment for a variety of human activities. Prerequisite: GEGN468 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

GEGN573. GEOLOGICAL ENGINEERING SITE INVESTIGATION. 3.0 Semester Hrs.

(I) 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). 3 hours lecture; 3 semester hours.

GEGN575. APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS. 3.0 Semester Hrs.

(II) 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 evaluation and selection. Laboratories will use Macintosh and DOS-based personal computer systems for GIS projects, as well as video-presentations. Visits to local GIS laboratories, and field studies will be required. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN578. GIS PROJECT DESIGN. 1-3 Semester Hr.

(I, II) Project implementation of GIS analysis. Projects may be undertaken by individual students, or small student teams. Documentation of all project design stages, including user needs assessment, implementation procedures, hardware and software selection, data sources and acquisition, and project success assessment. Various GIS software may be used; projects may involve 2-dimensional GIS, 3-dimensional subsurface models, or multi-dimensional time-series analysis. Prerequisite: none. Variable credit, 1-3 semester hours, depending on project. Offered on demand.

GEGN580. APPLIED REMOTE SENSING FOR GEOENGINEERING AND GEOSCIENCES. 3.0 Semester Hrs.

(I) This course offers an introduction to remote sensing in general and radar remote sensing and optical remote sensing in specific as well as their applications to all areas of geoengineering and geosicences. Lecture topics include: principles SAR (Synthetic Aperture Radar) and InSAR (Interferometry of Synthetic Aperture Radar) and their applications, as well as basic concepts of optical remote sensing and its application in geoengineering and geosciences. Topics include various sensors and platforms of SAR data acquisition, SAR data access, SAR data processing, data acquisition and processing of optical remote sensing images. Prerequisites: Graduate standing. 2 hours lecture, 3 hours lab, 3 semester hours.

GEGN581. ANALYTICAL HYDROLOGY. 3.0 Semester Hrs.

Equivalent with GEGN481,

(I) Introduction to the theory, and hydrological application of, probability, statistics, linear algebra, differential equations, numerical analysis, and integral transforms. The course will require more challenging assignments and exams commensurate with graduate credit. Prerequisites: GEGN467. 3 hours lecture; 3 semester hours.

GEGN582. INTEGRATED SURFACE WATER HYDROLOGY. 3.0 Semester Hrs.

Equivalent with ESGN582,

(I) This course provides a quantitative, integrated view of the hydrologic cycle. The movement and behavior of water in the atmosphere (including boundary layer dynamics and precipitation mechanisms), fluxes of water between the atmosphere and land surface (including evaporation, transpiration, precipitation, interception and through fall) and connections between the water and energy balances (including radiation and temperature) are discussed at a range of spatial and temporal scales. Additionally, movement of water along the land surface (overland flow and snow dynamics) and in the subsurface (saturated and unsaturated flow) as well as surface-subsurface exchanges and runoff generation are also covered. Finally, integration and connections within the hydrologic cycle and scaling of river systems are discussed. Prerequisites: Groundwater Engineering (GEGN466/GEGN467), Fluid Mechanics (GEGN351/ EGGN351), math up to differential equations, or equivalent classes. 3 hours lecture; 3 semester hours.

GEGN583. MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS. 3.0 Semester Hrs.

(II) Lectures, assigned readings, and direct computer experience concerning the fundamentals and applications of finite-difference and finite-element numerical methods and analytical solutions to ground water flow and mass transport problems. Prerequisite: A knowledge of FORTRAN programming, mathematics through differential and integral calculus, and GEGN467. 3 hours lecture; 3 semester hours.

GEGN584. FIELD METHODS IN HYDROLOGY. 3.0 Semester Hrs.

(I) Design and implementation of tests that characterize surface and subsurface hydrologic systems, including data logger programming, sensor calibration, pumping tests, slug tests, infiltration tests, stream gauging and dilution measurements, and geophysical (EM, resistivity, and/or SP) surveys. Prerequisites: Groundwater Engineering (GEGN466/ GEGN467, Surface Water Hydrology (ESGN582) or equivalent classes. 2 hours lecture; 5 hours lab and field exercises one day of the week. Days TBD by instructor; 3 semester hours.

GEGN585. FLUID MECHANICS FOR HYDROLOGY. 2.0 Semester Hrs.

(I) This class focuses on the fundamental concepts of engineering fluid mechanics as they relate to the study of hydrology. Topics include fluid statics, dynamics, continuity, energy and momentum, dimensional analysis and open channel flow. 2 hours lecture; 2 semester hours.

GEGN586. NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS. 3.0 Semester Hrs.

(II) This course provides quantitative methods for evaluating the geochemical characteristics of geological systems. The course is project based with lectures to provide information about the topic and use of geochemical modeling software. Student projects consist of chemical speciation of waters, activity diagrams, reaction progress models, water-rock interactions, sorption and surface complexation, and kinetic mineral reactions. Students complete an individual project on the geochemical system of their choice and present it to the class. Prerequisite: CEEN550 or CHGC509. 3 hours lecture, 3 semester hours. Offered spring semester, odd years.

GEGN598. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEGN599. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEGN669. ADVANCED TOPICS IN ENGINEERING HYDROGEOLOGY. 1-2 Semester Hr.

(I, II) Review of current literature and research regarding selected topics in hydrogeology. Group discussion and individual participation. Guest speakers and field trips may be incorporated into the course. Prerequisite: none. 1 to 2 semester hours; may be repeated for credit.

GEGN670. ADVANCED TOPICS IN GEOLOGICAL ENGINEERING. 3.0 Semester Hrs.

(I, II) Review of current literature and research regarding selected topics in engineering geology. Group discussion and individual participation. Guest speakers and field trips may be incorporated into the course. Prerequisite: none. 3 hours lecture; 3 semester hours. Repeatable for credit under different topics.

GEGN671. LANDSLIDES: INVESTIGATION, ANALYSIS & MITIGATION. 3.0 Semester Hrs.

(I) Geological investigation, analysis, and design of natural rock and soil slopes and mitigation of unstable slopes. Topics include landslide types and processes, triggering mechanisms, mechanics of movements, landslide investigation and characterization, monitoring and instrumentation, soil slope stability analysis, rock slope stability analysis, rock fall analysis, stabilization and risk reduction measures. Prerequisites: GEGN468, EGGN361, MNGN321, (or equivalents). 3 hours lecture; 3 semester hours.

GEGN672. ADVANCED GEOTECHNICS. 3.0 Semester Hrs.

Practical analysis and application of techniques in weak rock engineering, ground-water control in construction, fluvial stabilization and control, earthquake hazard assessment, engineering geology in construction, engineering geology in dam investigation, and other current topics in geotechnics practice. Prerequisite: GEGN468, CEEN312, CEEN312L and MNGN321. 3 hours lecture; 3 semester hours. Offered alternate years.

GEGN673. ADVANCED GEOLOGICAL ENGINEERING DESIGN. 3.0 Semester Hrs.

(II) Application of geological principles and analytical techniques to solve complex engineering problems related to geology, such as mitigation of natural hazards, stabilization of earth materials, and optimization of construction options. Design tools to be covered will include problem solving techniques, optimization, reliability, maintainability, and economic analysis. Students will complete independent and group design projects, as well as a case analysis of a design failure. 3 hours lecture; 3 semester hours. Offered alternate years.

GEGN681. VADOSE ZONE HYDROLOGY. 3.0 Semester Hrs.

(II) Study of the physics of unsaturated groundwater flow and contaminant transport. Fundamental processes and data collection methods will be presented. The emphasis will be on analytic solutions to the unsaturated flow equations and analysis of field data. Application to non-miscible fluids, such as gasoline, will be made. The fate of leaks from underground tanks will be analyzed. Prerequisites: GEGN467 or equivalent; Math through Differential Equations. 3 hours lecture; 3 semester hours.

GEGN682. FLOW AND TRANSPORT IN FRACTURED ROCK. 3.0 Semester Hrs.

(I) Explores the application of hydrologic and engineering principles to flow and transport in fractured rock. Emphasis is on analysis of field data and the differences between flow and transport in porous media and fractured rock. Teams work together throughout the semester to solve problems using field data, collect and analyze field data, and do independent research in flow and transport in fractured rock. Prerequisites: GEGN581. 3 hours lecture; 3 credit hours. Offered alternate years.

GEGN683. ADVANCED GROUND WATER MODELING. 3.0 Semester Hrs.

(II) Flow and solute transport modeling including: 1) advanced analytical modeling methods; 2) finite elements, random-walk, and method of characteristics numerical methods; 3) discussion of alternative computer codes for modeling and presentation of the essential features of a number of codes; 4) study of selection of appropriate computer codes for specific modeling problems; 5) application of models to ground water problems; and 6) study of completed modeling projects through literature review, reading and discussion. Prerequisite: GEGN509/CHGC509 or GEGN583. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEGN699. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

GEGX571. GEOCHEMICAL EXPLORATION. 3.0 Semester Hrs.

(I) Dispersion of trace metals from mineral deposits and their discovery. Laboratory consists of analysis and statistical interpretation of data of soils, stream sediments, vegetation, and rock in connection with field problems. Term report required. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL501. APPLIED STRATIGRAPHY. 4.0 Semester Hrs.

(I) Review of basic concepts in siliciclastic and carbonate sedimentology and stratigraphy. Introduction to advanced concepts and their application to exploration and development of fossil fuels and stratiform mineral deposits. Modern facies models and sequence-stratigraphic concepts applied to solving stratigraphic problems in field and subsurface settings. Prerequisites: GEOL314 or equivalent. 3 hours lecture, 4 hours lab; 4 semester hours.

GEOL502. STRUCTURAL METHODS FOR SEISMIC INTERPRETATION. 3.0 Semester Hrs.
(I) A practical course that covers the wide variety of structural methods and techniques that are essential to produce a valid and coherent interpretation of 2D and 3D seismic reflection data in structurally complex areas. Topics covered include: Extensional tectonics, fold and thrust belts, salt tectonics, inversion tectonics and strike-slip fault systems. Laboratory exercises are based on seismic datasets from a wide variety of structural regimes from across the globe. The course includes a 4 day field trip to SE Utah. Prerequisite: GEOL309 and GEOL314 or GEOL315, or equivalents. 3 hours lecture/lab; 3 semester hours.

GEOL503. INTEGRATED GEOLOGICAL INTERPRETATION OF 3D SEISMIC DATA. 3.0 Semester Hrs.
(II) INTEGRATED GEOLOGICAL INTERPRETATION OF 3D SEISMIC DATA-A PRACTICAL COURSE IN SEISMIC INTERPRETATION OF GLOBAL DATASETS. A practical course in workstation based, integrated geological interpretation of 3D seismic reflection data. Course builds directly on the seismic interpretation skills learnt in the prerequisite GEOL502 Structural Methods for Seismic Interpretation. Key concepts developed in this course are: making internally consistent interpretations of complex 3D datasets and developing integrated geological (structural and stratigraphic) interpretations of 3D seismic data. Prerequisite: GEOL502. 3 hours lecture/lab; 3 semester hours.

GEOL505. ADVANCED STRUCTURAL GEOLOGY. 3.0 Semester Hrs.
(I) Advanced Structural Geology builds on basic undergraduate Structural Geology. Structures such as folds, faults, foliations, lineations and shear zones will be considered in detail. The course focuses on microstructures, complex geometries and multiple generations of deformation. The laboratory consists of microscopy, in-class problems, and some field-based problems. Prerequisites: GEGN307, GEOL309, GEGN316, GEOL321, or equivalents. 2 hours lecture, 2 hours lab, and field exercise; 3 semester hours.

GEOL512. MINERALOGY AND CRYSTAL CHEMISTRY. 3.0 Semester Hrs.
(I) Relationships among mineral chemistry, structure, crystallography, and physical properties. Systematic treatments of structural representation, defects, mineral stability and phase transitions, solid solutions, substitution mechanisms, and advanced methods of mineral identification and characterization. Applications of principles using petrological and environmental examples. Prerequisites: GEOL321, DCGN209 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

GEOL513. HYDROTHERMAL GEOCHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGC513,
(II) Geochemistry of high-temperature aqueous systems. Examines fundamental phase relationships in model systems at elevated temperatures and pressures. Major and trace element behavior during fluid-rock interaction. Theory and application of stable isotopes as applied to hydrothermal mineral deposits. Review of the origin of hydrothermal fluids and mechanisms of transport and deposition of ore minerals. Includes the study of the geochemistry of magmatic aqueous systems, geothermal systems, and submarine hydrothermal vents. Prerequisites: GEGN401. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL514. BUSINESS OF ECONOMIC GEOLOGY. 3.0 Semester Hrs.
Examines the business side of mineral exploration including company structure, fundraising, stock market rules and regulations, and legal environment. Reviews the types of minerals exploration companies, differences between mineral sectors, rules and practices of listing a minerals company on a stock exchange, and legal requirements of listing and presenting data to stockholders. The course is centered on lectures by industry representatives from the Denver area. Includes participation in a technical conference in Vancouver or Toronto and meetings with lawyers, stockbrokers, and geoscientists working in the mineral industry. Prerequisites: GEGN401. 3 hours lecture and seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

GEOL515. ADVANCED MINERAL DEPOSITS. 3.0 Semester Hrs.
(I) Geology of mineral systems at a deposit, district, and regional scale formed by magmatic-hydrothermal, sedimentary/basinal, and metamorphic processes. Emphasis will be placed on a systems approach to evaluating metal and sulfur sources, transportation paths, and traps. Systems examined will vary by year and interest of the class. Involves a team-oriented research project that includes review of current literature and laboratory research. Prerequisites: GEGN401. 1 hour lecture, 5 hours lab; 3 semester hours. Repeatable for credit.

GEOL517. FIELD METHODS FOR ECONOMIC GEOLOGY. 3.0 Semester Hrs.
(II) Methods of field practices related to mineral exploration and mining. Lithology, structural geology, alteration, and mineralization vein-type precious metal deposits. Mapping is conducted both underground at the Edgar Test Mine and above ground in the Idaho Springs area. Drill core and rock chips from different deposit types are utilized. Technical reports are prepared for each of four projects. Class is run on Saturday (9 am-4 pm) throughout the semester. Prerequisites: GEGN401. 6 hours lab and seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

GEOL518. MINERAL EXPLORATION. 3.0 Semester Hrs.
(II) Mineral industry overview, deposit economics, target selection, deposit modeling, exploration technology, international exploration, environmental issues, program planning, proposal development. Team development and presentation of an exploration proposal. Prerequisite: GEOL515, GEOL520, or equivalent. 2 hours lecture/seminar, 3 hours lab; 3 semester hours. Offered when student demand is sufficient.

GEOL519. ABITIBI GEOLOGY AND EXPLORATION FIELD SCHOOL. 3.0 Semester Hrs.
(II, S) Methods of field practices related to mineral exploration and mining. Regional and deposit-scale geology of Archean mineral deposits, including lode gold deposits and volcanic-hosted massive sulfide deposits. Includes mineral prospect evaluation, structural geology, physical volcanology, deposit definition, alteration mapping, mining methods, ore processing, and metallurgy. Core logging, underground stope mapping, open pit mapping, lithogeochemical sampling, and field-analytical techniques. Course involves a seminar in the spring semester that focuses on the geology and deposit types in the area to be visited. An intense 14-day field trip is run in the summer semester. Each day includes up to 4 hours of instruction in the field and 4 hours of team-oriented field exercises. Prerequisites: none. 6 hours lab and seminar; 2 semester hours in spring, 1 semester hour in summer. Offered alternate years when student demand is sufficient.

GEOL520. NEW DEVELOPMENTS IN THE GEOLOGY AND EXPLORATION OF ORE DEPOSITS. 3.0 Semester Hrs.
(I, II) Each topic unique and focused on a specific mineral deposit type or timely aspects of economic geology. Review of the geological and geographic setting of a specific magmatic, hydrothermal, or sedimentary mineral deposit type. Detailed study of the physical and chemical characteristics of selected deposits and mining districts. Theory and application of geological field methods and geochemical investigations. Includes a discussion of genetic models, exploration strategies, and mining methods. Prerequistes: GEGN401. 2 hours lecture; 2 semester hours. Repeatable for credit.

GEOL521. FIELD AND ORE DEPOSIT GEOLOGY. 3.0 Semester Hrs.
(I, S) Field study of major mineral deposit districts inside and outside of the USA. Examines regional and deposit-scale geology. Underground and open pit mine visits and regional traverses. Topics addressed include deposit definition, structural geology, alteration mapping, mining methods, and ore processing. Course involves a seminar in the spring semester that focuses on the geology and deposit types in the area to be visited. An intense 10-14 day field trip is run in the summer semester. Prerequisites: none. 6 hours lab and seminar; 2 semester hours in spring, 1 semester hour in summer. Offered alternate years when student demand is sufficient. Repeatable for credit.

GEOL522. TECTONICS AND SEDIMENTATION. 3.0 Semester Hrs.
(II) Application and integration of advanced sedimentologic and stratigraphic concepts to understand crustal deformation at a wide range of spatial- and time-scales. Key concepts include: growth-strata analysis, interpretation of detrital composition (conglomerate unroofing sequences and sandstone provenance trends), paleocurrent deflection and thinning trends, tectonic control on facies distribution and basic detrital zircon and fission track analysis. Students will read a wide range of literature to explore the utility and limitation of traditional "tectonic signatures" in stratigraphy, and will work on outcrop and subsurface datasets to master these concepts. Special attention is paid to fold-thrust belt, extensional and salt-related deformation. The course has important applications in Petroleum Geology, Geologic Hazards, and Hydrogeology. Required: 2-3 fieldtrips, class presentations, and a final paper that is written in a peer-reviewed journal format. Prerequisites: GEOL314 or equivalent, and GEOL309 or equivalent. 3 hours lecture and seminar; 3 semester hours. Offered even years.

GEOL523. REFLECTED LIGHT AND ELECTRON MICROSCOPY. 2.0 Semester Hrs.
(I) Theoretical and practical aspects of reflected light and electron microscopy. Emphasis will be placed on applications to ore deposit exploration and research. Lecture and discussion topics will highlight both standard and new techniques and instrumentation including SEM and QEMSCAN, as well as key questions in mineral deposit genesis which can be addressed using reflected light and electron microscopy. Includes detailed study of a selected suite of samples, with emphasis on mineral identification, textural relationships, paragenetic sequences, and mineral chemistry. Course culminates in a project. Prerequisites: GEGN401. 1 hour lecture; 3 hours lab; 2 semester hours.

GEOL525. PRINCIPLES OF METAMORPHIC GEOLOGY. 3.0 Semester Hrs.
(I) Study of metamorphic processes and products that occur on Earth at the micro- to the macro-scale. Areas of focus include (a) the nature of metamorphism in subduction zones and continental interiors, (b) the mechanisms and physico-chemical effects of fluid-rock and melt-rock interactions, (c) links between metamorphism and ore-forming processes, and (d) combining metamorphism with geochemistry, isotope geochronology, and structural geology to quantify the tectonothermal evolution of the lithosphere throughout space and time. Laboratory exercises emphasize the examination, identification, and interpretation of metamorphic minerals and microstructures in hand sample and down the microscope, and the calculation and application of thermodynamically constrained phase equilibria to describe and predict the pressure-temperature evolution of rocks and terranes. Short field excursions to local sites of metamorphic interest. Offered every other year. Prerequisites: GEOL321 and GEGN307. 2 hours lecture; 3 hours lab; 3 semester hours.

GEOL535. LITHO ORE FORMING PROCESSES. 3.0 Semester Hrs.
(I, II, S) Lithogeochemistry is the study of fluid-rock interaction in hydrothermal systems from a mineralogical perspective. Practical course on numerical modeling of fluid-rock interaction combined with observations of mineral assemblages in rocks and thin sections taking hydrothermal ore deposits as test examples including pegmatites and veins, greisen alteration, porphyry systems and REE deposits. Mechanisms of metal complexation, transport and mineralization processes in hydrothermal fluids are connected to mineral alteration textures, mineral/rock geochemistry and mineral paragenesis. Includes a mine visit if available. Prerequisites: GEOL321, GEGN401. 2 hours lecture; 3 hours lab, 3 semester hours.

GEOL540. ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY. 3.0 Semester Hrs.
(II) A study of the principles of geochronology and stable isotope distributions with an emphasis on the application of these principles to important case studies in igneous petrology and the formation of ore deposits. U, Th, and Pb isotopes, K-Ar, Rb-Sr, oxygen isotopes, hydrogen isotopes, and carbon isotopes included. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL550. INTEGRATED BASIN MODELING. 3.0 Semester Hrs.
(I) This course introduces students to principal methods in computer-based basin modeling: structural modeling and tectonic restoration; thermal modeling and hydrocarbon generation; and stratigraphic modeling. Students apply techniques to real data set that includes seismic and well data and learn to integrate results from multiple approaches in interpreting a basin's history. The course is primarily a lab course. Prerequisite: none. A course background in structural geology, sedimentology/stratigraphy or organic geochemistry will be helpful. 1 hour lecture, 5 hours labs; 3 semester hours.

GEOL551. APPLIED PETROLEUM GEOLOGY. 3.0 Semester Hrs.
(II) Subjects to be covered include computer subsurface mapping and cross sections, petrophysical analysis of well data, digitizing well logs, analyzing production decline curves, creating hydrocarbon-porosity-thickness maps, volumetric calculations, seismic structural and stratigraphic mapping techniques, and basin modeling of hydrocarbon generation. Students are exposed to three software packages used extensively by the oil and gas industry. Prerequisite: GEGN438 or GEOL609. 3 hours lecture; 3 semester hours.

GEOL552. UNCONVENTIONAL PETROLEUM SYSTEMS. 3.0 Semester Hrs.

(II) Unconventional petroleum systems have emerged as a critical and indispensable part of current US production and potential future reserves. Each of the 5 unconventional oil and 4 unconventional gas systems will be discussed: what are they, world wide examples, required technology to evaluate and produce, environmental issues, and production/resource numbers. The oil part of the course will be followed by looking at cores from these systems. The gas part of the course will include a field trip to the Denver, Eagle, and Piceance Basins in Colorado to see outstanding outcrops of actual producing units. Prerequisites: GEGN438 or GEOL609, GEGN527. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL553. GEOLOGY AND SEISMIC SIGNATURES OF RESERVOIR SYSTEMS. 3.0 Semester Hrs.

(II) This course is a comprehensive look at the depositional models, log signatures, characteristics, and seismic signatures for all the main reservoirs we explore for and produce from in the subsurface. The first half is devoted to the clastic reservoirs (12 in all); the second part to the carbonate reservoirs (7 total). The course will utilize many hands-on exercises using actual seismic lines for the various reservoir types. Prerequisites: GEOL501 or GEOL314. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL555. STRUCTURAL FIELD RESEARCH. 4.0 Semester Hrs.

(I) This course focuses on geological field work along the Colorado Front Range through inquiry-based research and hypothesis-testing. The type of problems students will work on will vary from more applied problems (e.g. centered around the Edgar mine) or more academic/scientific orientated problems, depending on the student?s interest. The class will be split up in groups of students with similar interests. In the first part of the course, we take an introductory two-day field trip, and students will review existing literature and maps and write a brief research proposal including hypotheses, tests and a work plan for the remainder of the course. The second part of the course will focus on field work. During the last part of the course, students prepare a geological map and appropriate cross sections, and a report presenting rock descriptions, structural analysis, a geological history, and interpretation of results in the context of the hypotheses posed. Prerequisites: (need previous field experience such as a field course, and a course in structural geology and one in earth materials). 2 hours lecture, 6 hours lab; 4 semester hours.

GEOL560. IMPERIAL BARREL AAPG COMPETITION CLASS. 3.0 Semester Hrs.

(II) The course is designed for geoscience students to evaluate as a team a geophysical and geological dataset. The date set consists of seismic, well data, geochemical information, and geophysical logs. The class provides students with an insight into the hydrocarbon exploration business. A petroleum geology background is useful but not required. A team will compete at the Rocky Mountain Section competition and go onto the Annual American Association of Petroleum Geologist (AAPG) meeting competition if they win the section competition. The class is intended for graduate students only. 3 hours lecture; 3 semester hours.

GEOL565. RISKS AND VOLUMES ASSESSMENT FOR CONVENTIONAL AND UNCONVENTIONAL PROSPECTS AND PLAYS. 3.0 Semester Hrs.

(II) Students learn to translate geological knowledge into sound and realistic numbers and ranges for consistent risk and volume assessment of exploration prospects. Prerequisite: GEGN438. 3 hours lecture; 3 semester hours.

GEOL570. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.

(II) 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. Prerequisites: PHGN200 and MATH225. 2 hours lecture, 2 hours lab; 3 semester hours.

GEOL575. PETROLEUM SYSTEMS ANALYSIS. 3.0 Semester Hrs.

(I, II, S) The goal is to learn how to analyze petroleum systems and use tools of petroleum geochemistry and basin modeling to find, appraise and produce oil and gas. Prerequisites: GEGN438. 3 hours lecture; 3 semester hours.

GEOL585. APPLICATION OF SEISMIC GEOMORPHOLOGY. 3.0 Semester Hrs.

(I) Seismic Geomorphology is the study of landforms imaged in 3-D seismic data, for the purpose of understanding the history, processes and fill architecture of a basin. This course will review both qualitative and quantitative approaches to interpreting and applying seismic geomorphologic observations in basin exploration and development. Examples from Gulf of Mexico, Indonesia, Trinidad, Morocco, New Zealand and other basins of the world will be used to illustrate the techniques for interpreting the depositional elements of fluvial, deltaic, shoreline, shelf, deep water clastic systems, as well as delineating geohazards, and for quantifying and using those data to predict reservoir distribution and architecture, body geometries, planning field developments and assessing uncertainty. This introductory look at the tool of seismic geomorphology is suitable for any geoscientists or engineers looking to enhance their understanding of ancient depositional systems imaged in seismic data. 3 hours lecture; 3 semester hours.

GEOL598. SEMINAR IN GEOLOGY OR GEOLOGICAL 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). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEOL599. INDEPENDENT STUDY IN GEOLOGY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEOL601. CORE TO OUTCROP STRATIGRAPHY. 2.0 Semester Hrs.

(II) A seminar series integrating core and outcrop observations with class discussions. Topics range from global to regional scale tectono-stratigraphy to process sedimentology. Discussions are based on reading journal papers combined with core observations. Field trip encompasses a series of outcrop-based projects/exercises. Prerequisite: GEOL501. 2 hours seminar; 2 semester hours.

GEOL608. HISTORY OF GEOLOGICAL CONCEPTS. 3.0 Semester Hrs.
(I) Lectures and seminars concerning the history and philosophy of the science of geology; emphasis on the historical development of basic geologic concepts. Course is an elective for doctoral candidates in department. 3 hours lecture; 3 semester hours.

GEOL609. ADVANCED PETROLEUM GEOLOGY. 3.0 Semester Hrs.
(II) Subjects to be covered involve consideration of basic chemical, physical, biological and geological processes and their relation to modern concepts of oil/gas generation (including source rock deposition and maturation), and migration/accumulation (including that occurring under hydrodynamic conditions). Concepts will be applied to the historic and predictive occurrence of oil/gas to specific Rocky Mountain areas. In addition to lecture attendance, course work involves review of topical papers and solution of typical problems. Prerequisite: GEGN438. 3 hours lecture; 3 semester hours.

GEOL610. ADVANCED SEDIMENTOLOGY. 3.0 Semester Hrs.
(I) Keynote lectures, mixed with discussions, in-class exercises, core and field observations in a seminar series on sedimentology. Introduction to current hot topics in sedimentology, and discussions on fundamental principles. Specific topics vary yearly depending on most recent advancements and course participant?s interests. Quantitative sedimentology. Applications of sedimentology. All seminars are based on reading and discussing journal papers. Field trip to a modern environment. Essays and presentations required. Prerequisite: GEOL501. Acceptable to take GEOL610 at the same time, as GEOL501. 3 hours lecture and seminar; 3 semester hours. Offered alternate years.

GEOL611. SEQUENCE STRATIGRAPHY IN SEISMIC, WELL LOGS, AND OUTCROP. 3.0 Semester Hrs.
(I) Keynote lectures and a seminar series on the sequence stratigraphy of depositional systems, including both siliciclastics and carbonates and how they behave in changing sea-level, tectonic subsidence, and sediment supply conditions. Application of sequence stratigraphy concepts to reflection seismic, well-log, and outcrop datasets. Field trip and report required. Prerequisite: GEOL501. 3 hours lecture and seminar; 3 semester hours.

GEOL613. GEOLOGIC RESERVOIR CHARACTERIZATION. 3.0 Semester Hrs.
(I, II) Principles and practice of characterizing petro leum reservoirs using geologic and engineering data, including well logs, sample descriptions, routine and special core analysis and well tests. Emphasis is placed on practical analysis of such data sets from a variety of clastic petroleum reservoirs worldwide. These data sets are integrated into detailed characterizations, which then are used to solve practical oil and gas field problems. Prerequisites: GEGN438, GEOL501, GEOL505 or equivalents. 3 hours lecture; 3 semester hours.

GEOL617. THERMODYNAMICS AND MINERAL PHASE EQUILIBRIA. 3.0 Semester Hrs.
(I) Basic thermodynamics applied to natural geologic systems. Evaluation of mineral-vapor mineral solution, mineral-melt, and solid solution equilibria with special emphasis on oxide, sulfide, and silicate systems. Experimental and theoretical derivation, use, and application of phase diagrams relevant to natural rock systems. An emphasis will be placed on problem solving rather than basic theory. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL621. PETROLOGY OF DETRITAL ROCKS. 3.0 Semester Hrs.
(II) Compositions and textures of sandstones, siltstones, and mudrocks. Relationship of compositions and textures of provenance, environment of deposition, and burial history. Development of porosity and permeability. Laboratory exercises emphasize use of petrographic thin sections, x-ray diffraction analysis, and scanning electron microscopy to examine detrital rocks. A term project is required, involving petrographic analysis of samples selected by student. Pre-requisites: GEGN206 , GEOL321 or equivalent. 2 hours lecture and seminar, 3 hours lab; 3 semester hours. Offered on demand.

GEOL624. CARBONATE SEDIMENTOLOGY AND PETROLOGY. 3.0 Semester Hrs.
(II) Processes involved in the deposition of carbonate sediments with an emphasis on Recent environments as analogs for ancient carbonate sequences. Carbonate facies recognition through bio- and lithofacies analysis, three-dimensional geometries, sedimentary dynamics, sedimentary structures, and facies associations. Laboratory stresses identification of Recent carbonate sediments and thin section analysis of carbonate classification, textures, non-skeletal and biogenic constituents, diagenesis, and porosity evolution. Prerequisite: GEOL321 and GEOL314. 2 hours lecture/seminar, 2 hours lab; 3 semester hours.

GEOL628. ADVANCED IGNEOUS PETROLOGY. 3.0 Semester Hrs.
(I) Igneous processes and concepts, emphasizing the genesis, evolution, and emplacement of tectonically and geochemically diverse volcanic and plutonic occurrences. Tectonic controls on igneous activity and petrochemistry. Petrographic study of igneous suites, mineralized and non-mineralized, from diverse tectonic settings. Prerequisites: GEOL321, GEGN206. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

GEOL642. FIELD GEOLOGY. 1-3 Semester Hr.
(S) Field program operated concurrently with GEGN316 field camp to familiarize the student with basic field technique, geologic principles, and regional geology of Rocky Mountains. Prerequisite: Undergraduate degree in geology and GEGN316 or equivalent. During summer field session; 1 to 3 semester hours.

GEOL643. GRADUATE FIELD SEMINARS. 1-3 Semester Hr.
(I, II, S) Special advanced field programs emphasizing detailed study of some aspects of geology. Normally conducted away from the Golden campus. Prerequisite: Restricted to Ph.D. or advanced M.S. candidates. Usually taken after at least one year of graduate residence. Background requirements vary according to nature of field study. Fees are assessed for field and living expenses and transportation. 1 to 3 semester hours; may be repeated for credit.

GEOL645. VOLCANOLOGY. 3.0 Semester Hrs.
(II) Assigned readings and seminar discussions on volcanic processes and products. Principal topics include pyroclastic rocks, craters and calderas, caldron subsidence, diatremes, volcanic domes, origin and evolution of volcanic magmas, and relation of volcanism to alteration and mineralization. Petrographic study of selected suites of lava and pyroclastic rocks in the laboratory. Prerequisite: none. 1 hour seminar, 6 hours lab; 3 semester hours.

GEOL653. CARBONATE DIAGENESIS AND GEOCHEMISTRY. 3.0 Semester Hrs.

(II) Petrologic, geochemical, and isotopic approaches to the study of diagenetic changes in carbonate sediments and rocks. Topics covered include major near-surface diagenetic environments, subaerial exposure, dolomitization, burial diagenesis, carbonate aqueous equilibria, and the carbonate geochemistry of trace elements and stable isotopes. Laboratory stresses thin section recognition of diagenetic textures and fabrics, x-ray diffraction, and geochemical/isotopic approaches to diagenetic problems. Prerequisites: GEOL624. 2 hours lecture; 3 hours lab; 3 semester hours.

GEOL660. CARBONATE RESERVOIRS - EXPLORATION TO PRODUCTION ENGINEERING. 3.0 Semester Hrs.

Equivalent with PEGN660,

(II) An introduction to the reservoir characterization of carbonate rocks, including geologic description, petrophysics, and production engineering. Develops an understanding of the integration of geology, rock physics, and engineering to improve reservoir performance. Application of reservoir concepts in hands-on exercises that include reflection seismic, well-log, and core data. 3 hours lecture; 3 semester hours.

GEOL698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEOL699. INDEPENDENT STUDY IN GEOLOGY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEOL707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Geophysics

Degrees Offered

- Professional Masters in Petroleum Reservoir Systems
- Master of Science (Geophysics)
- Master of Science (Geophysical Engineering)
- Doctor of Philosophy (Geophysics)
- Doctor of Philosophy (Geophysical Engineering)

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 an interdisciplinary field, a rich blend of disciplines such as geology, physics, mathematics, computer science, and electrical engineering. Professionals working in the field of geophysics often come from programs in these allied disciplines, as well as from formal programs in geophysics.

Geophysicists study and explore the Earth's interior through physical measurements collected at the Earth's surface, in boreholes, from aircraft, and from satellites. Using a combination of mathematics, physics, geology, computer science, hydrology, and chemistry, a geophysicist analyzes these measurements to infer properties and processes within the Earth's complex interior. Noninvasive imaging beneath the surface of Earth and other planets by geophysicists is analogous to noninvasive imaging of the interior of the human body by medical specialists.

The Earth supplies all materials needed by our society, serves as the repository of used products, and provides a home to all its inhabitants. Therefore, geophysics and geophysical engineering have important roles to play in the solution of challenging problems facing the inhabitants of this planet, such as providing fresh water, food, and energy for Earth's growing population, evaluating sites for underground construction and containment of hazardous waste, monitoring noninvasively the aging infrastructures (natural gas pipelines, water supplies, telecommunication conduits, transportation networks) of developed nations, mitigating the threat of geohazards (earthquakes, volcanoes, landslides, avalanches) to populated areas, contributing to homeland security (including detection and removal of unexploded ordnance and land mines), evaluating changes in climate and managing humankind's response to them, and exploring the Earth and other planets.

Energy companies and mining firms employ geophysicists to explore for hidden resources around the world. Engineering firms hire geophysical engineers to assess the Earth's near-surface properties when sites are chosen for large construction projects and waste-management operations. Environmental organizations use geophysics to conduct groundwater surveys and to track the flow of contaminants. On the global scale, geophysicists employed by universities and government agencies (such as the United States Geological Survey and NASA), try to understand such Earth processes as heat flow, gravitational, magnetic, electric, thermal, and stress fields within the Earth's interior. For the past decade, 100% of CSM's geophysics graduates have found employment in their chosen field.

With nearly 20 active faculty members and small class sizes, students receive individualized attention in a close-knit environment. Given the interdisciplinary nature of geophysics, the graduate curriculum requires students to become thoroughly familiar with geological, mathematical, and physical theory, in addition to exploring the theoretical and practical aspects of the various geophysical methodologies.

Research Emphasis

The Department conducts research in a wide variety of areas that are mostly related, but not restricted, to applied geophysics. Candidates interested in the current research activities of specific faculty members are encouraged to visit the Department's website and to contact that faculty member directly. To give prospective candidates an idea of the types of research activities available in geophysics at CSM, a list of the recognized research groups operating within the Department of Geophysics, and information about other research strengths in the Department, is given below.

The Center for Wave Phenomena (CWP) is a research group with four faculty members from the Department of Geophysics. With research sponsored by approximately 25 companies worldwide in the petroleum exploration industry, plus U.S. government agencies, CWP emphasizes the development of theoretical and computational methods for imaging of the Earth's subsurface, primarily through use of the reflection seismic method. Researchers have been involved in forward and inverse problems of wave propagation as well as data processing for data obtained where the subsurface is complex, specifically where it is both heterogeneous and anisotropic. CWP faculty and students actively work on large-scale cluster and GPU computing. Further information about CWP can be obtained at https://cwp.mines.edu/.

The Reservoir Characterization Project (RCP) integrates the acquisition and interpretation of 3D multicomponent time-lapse seismic reflection and downhole data with geology and petroleum engineering information of existing oil fields to solve complex reservoir challenges and gain improvements in reservoir performance prediction and development optimization. RCP's unique research model emphasizes a multidisciplinary, collaborative approach for practical research. It is an industry-funded research consortium with faculty and graduate-level students from Geophysics, Petroleum Engineering, and Geology disciplines. Read more about RCP at http://rcp.mines.edu/.

The Center for Gravity, Electrical & Magnetic Studies (CGEM) in the Department of Geophysics is an academic research center that focuses on the quantitative interpretation of gravity, magnetic, electrical and electromagnetic, and surface nuclear magnetic resonance (NMR) data in applied geophysics. The center brings together the diverse expertise of faculty and students in these different geophysical methods and works towards advancing the state of art in geophysical data interpretation for real-world problems. The emphases of CGEM research are processing and inversion of applied geophysical data. The primary areas of application include petroleum exploration and production, mineral exploration, geothermal, and geotechnical and engineering problems. In addition, environmental problems, infrastructure mapping, archaeology, hydrogeophysics, and crustal studies are also research areas within the Center. There are currently five major focus areas of research within CGEM: Gravity and Magnetics Research Consortium (GMRC), mineral exploration, geothermal exploration, surface NMR, and hydrogeophysics. Research funding is provided by petroleum and mining industries, ERDC, SERDP, DOE, and other agencies. More information about CGEM is available on the web at: http://cgem.mines.edu/.

The Electromagnetic Resource Exploration Group (EMREX) is involved in a wide variety of electromagnetic projects ranging from applied resource exploration to the basic science of induction hazards. Projects include studies of steel borehole casing distortion of electromagnetic data collected for reservoir characterization, marine mineral exploration using transient electromagnetic methods, characterization of powerline noise in airborne electromagnetic surveys, inductive coupling in conventional induced polarization surveys for mineral exploration, effects of magnetic storms on power grids via electromagnetic coupling, and the construction of an autonomous robot for geophysical data acquisition. Current external collaborators and sponsors include Newmont, Shell, the University of Toronto, the University of Illinois Urbana-Champaign, Helmholtz-Zentrum für Ozeanforschung Kiel (Geomar) and the USGS. More information is available at http://inside.mines.edu/EMRX-overview.

Global seismology research investigates using 3D numerical seismic wave simulations to improve our understanding of the Earth's interior, by linking observed data to advances in theory and numerical methods in wave propagation and optimization techniques.

Hydrogeophysics and porous media research focuses on combining geoelectrical (DC resistivity, complex conductivity, self-potential, and EM) and gravity methods with rock physics models at various scales and for various applications including the study of contaminant plumes, geothermal systems, leakage in earth dams and embankments, and active volcanoes.

Another research strength of the Department is in rock physics, which focuses on rock and fluid properties for basic science as well as for exploration and industrial applications. The primary goal of exploration and production geophysics is to identify fluids, specifically hydrocarbons, in rocks. These applications are successful only with a fundamental understanding of the physical phenomena of transport and storage properties as well as the interactions between fluids and rocks. Rock physics projects center on polar and non-polar fluid storage, fluid distributions and storage in rocks and how these distributions affect characteristics such as wave attenuation, velocity dispersion and seismic signatures.

Program Requirements

The Department offers both traditional, research-oriented graduate programs and a non-thesis professional education program designed to meet specific career objectives. The program of study is selected by the student, in consultation with an advisor, and with thesis committee approval, according to the student's career needs and interests. Specific degrees have specific requirements as detailed below.

Geophysics and Geophysical Engineering Program Objectives

The principal objective for students pursuing the PhD degree in Geophysics or Geophysical Engineering is: Geophysics PhD graduates will be regarded by their employers as effective teachers and/or innovative researchers in their early-career peer group. In support of this objective, the PhD programs in the Department of Geophysics are aimed at achieving these student outcomes:

- Graduates will command superior knowledge of Geophysics and fundamental related disciplines.
- Graduates will independently be able to conduct research leading to significant new knowledge and Geophysical techniques.
- Graduates will be able to report their findings orally and in writing.

The chief objective for students pursuing the MS degree in Geophysics or Geophysical Engineering is: Geophysics MS graduates will be regarded by their employers as effective practitioners addressing earth, energy and environmental problems with geophysical techniques. In support of this objective, the MS programs in the Department of Geophysics aim to achieve these student outcomes:

- Graduates will command superior knowledge of Geophysics and fundamental related disciplines.
- Graduates will be able to conduct original research that results in new knowledge and Geophysical techniques.
- Graduates will be able to report their findings orally and in writing.

Professional Masters in Petroleum Reservoir Systems

This is a multi-disciplinary, non-thesis master's degree for students interested in working as geoscience professionals in the petroleum industry. The Departments of Geophysics, Petroleum Engineering, and Geology and Geological Engineering share oversight for the Professional Masters in Petroleum Reservoir Systems program through a committee consisting of one faculty member from each department. Students gain admission to the program by application to any of the three sponsoring departments. Students are administered by that department into which they first matriculate. A minimum of 36 hours of course credit is required to complete the Professional Masters in Petroleum Reservoir Systems program. Up to 9 credits may be earned in 400-level courses. All other credits toward the degree must be 500 level or above. At least 9 hours must consist of:

One course selected from the following:		
GPGN419	INTRODUCTION TO FORMATION EVALUATION AND WELL LOGGING	3.0
or PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	
GPGN519	ADVANCED FORMATION EVALUATION	3.0
or PEGN519	ADVANCED FORMATION EVALUATION	
Two courses selected from the following:		
GEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	3.0
or PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	
GPGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	3.0
or GEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
or PEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
GPGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	3.0
or GEGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	
or PEGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	

Also, 9 additional hours must consist of one course from each of the 3 participating departments. The remaining 18 hours may consist of graduate courses from any of the 3 participating departments, or other courses approved by the committee. Up to 6 hours may consist of independent study, including an industry project.

Master of Science Degrees: Geophysics and Geophysical Engineering

Students may obtain a Master of Science (MS) Degree in either Geophysics or Geophysical Engineering, pursuant to the general and individual program requirements outlined below.

For either Master of Science degree, the minimum credits required include:

Course credits	26.0
Graduate research	12.0
Total Semester Hrs	38.0

While the student, with advisor and thesis committee approval, determines individual courses constituting the degree are determined by the student courses applied to all MS degrees must satisfy the following specific criteria:

- All course, research, transfer, residence, and thesis requirements are as described in Registration and Tuition Classification and Graduate Degrees and Requirements sections of the Catalog.
- Up to 9 credits may be satisfied through 400 (senior) level coursework. All remaining course credits applied to the degree must be at the 500 level or above.
- Students must include the following courses in their Master degree program:

LICM501	PROFESSIONAL ORAL COMMUNICATION	1.0
GPGN581	GRADUATE SEMINAR	1.0
GPGN707	GRADUATE RESEARCH CREDIT (beyond the required 26.0 course credits)	12.0

- Additional courses may also be required by the student's advisor and committee to fulfill background requirements as described below.

The coursework and thesis topic for the degree Master of Science, Geophysical Engineering, must meet the following specific requirements. Note that these requirements are in addition to those associated with the Master of Science in Geophysics.

- Students must complete, either prior to their arrival at CSM or while at CSM, no fewer than 16 credits of engineering coursework. What constitutes coursework considered as engineering is determined by the Geophysics faculty.
- The student’s dissertation topic must be appropriate for inclusion as part of an Engineering degree, as determined by the Geophysics faculty.

As described in the Master of Science, Thesis and Thesis Defense section of this Catalog, all MS candidates must successfully defend their MS thesis in a public oral Thesis Defense. The guidelines for the Thesis Defense enforced by the Department of Geophysics generally follow those outlined in in the Graduate Departments and Programs section of the Catalog, with one exception. The Department of Geophysics requires students submit the final draft of their written thesis to their thesis committee a minimum of three weeks prior to the thesis defense date.

Doctor of Philosophy Degrees: Geophysics and Geophysical Engineering

We invite applications to our Doctor of Philosophy (PhD) program not only from those individuals with a background in geophysics, but also from those whose background is in allied disciplines such as geology, physics, mathematics, computer science, or electrical engineering.

Students may obtain a PhD Degree in either Geophysics or Geophysical Engineering, pursuant to the general and individual program requirements outlined below.

For either PhD degree, at least 72 credits beyond the Bachelors Degree are required. Of that total, at least 24 research credits are required. At least 12 course credits must be completed in a minor program of study, approved by the candidate's PhD thesis committee. Up to 36 course credits may be awarded by the candidate's committee for completion of a thesis-based Master's Degree.

While individual courses constituting the degree are determined by the student and approved by the student's advisor and committee, courses applied to all PhD degrees must satisfy the following criteria:

- All course, research, minor degree programs, transfer, residence, and thesis requirements are as described in Registration and Tuition Classification and Graduate Degrees and Requirements sections of the Catalog.
- Up to 9 credits may be satisfied through 400 (senior) level coursework. All remaining course credits applied to the degree must be at the 500 level or above.
- Students must include the following courses in their PhD program:

LICM501	PROFESSIONAL ORAL COMMUNICATION	1.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS	1.0
GPGN681	GRADUATE SEMINAR - PHD	1.0
GPGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	24.0
Choose two of the following:		
SYGN501	RESEARCH SKILLS FOR GRADUATE STUDENTS	1.0
SYGN600	COLLEGE TEACHING	2.0
HASS601	ACADEMIC PUBLISHING	2-3

- Additional courses may also be required by the student's advisor and committee to fulfill background requirements described below.

The coursework and thesis topic for the degree Doctor of Philosophy, Geophysical Engineering, must meet the following additional requirements:

- Students must complete, either prior to their arrival at CSM or while at CSM, no fewer than 16 credits of engineering coursework. What constitutes coursework considered as engineering is determined by the Geophysics faculty.
- The student’s dissertation topic must be appropriate for inclusion as part of an Engineering degree, as determined by the Geophysics faculty.

Students in both PhD programs are also required to participate in a practical teaching experience. This requirement must be fulfilled, within a single semester and course, under observation and evaluation by the course instructor of record, and include:

- Planning and delivery of a minimum of 6 lecture hours, or 4 lecture hours and 2 labs;
- Creating and evaluating students' homework and laboratory reports, if appropriate; and
- Holding office hours if necessary.

In both PhD programs, students must demonstrate the potential for successful completion of independent research and enhance the breadth of their expertise by completing a Doctoral Research Qualifying Examination not later than two years from the date of enrollment in the program. An extension of one additional year may be petitioned by students through their thesis committees. In the Department of Geophysics, the Doctoral Research Qualifying Examination consists of the preparation, presentation, and defense of one research project and a thesis proposal. The research project and thesis proposal used in this process must conform to the standards posted on the Department of Geophysics website. As described in the Doctor of Philosophy Thesis Defense section of this catalog, all PhD candidates must successfully defend their PhD thesis in an open oral Thesis Defense. The guidelines for the Thesis Defense enforced by the Department of Geophysics follow those outlined in the Graduate Departments and Programs section of the Catalog, with one exception. The Department of Geophysics requires students submit the final draft of their written thesis to their thesis committee a minimum of three weeks prior to the thesis defense date.

Acceptable Thesis Formats

In addition to traditional dissertations, the Department of Geophysics also accepts dissertations that are compendia of papers published or submitted to peer-reviewed journals. Dissertations submitted in the latter format must adhere to the following guidelines.

- All papers included in the dissertation must have a common theme, as approved by a student’s thesis committee.
- Papers should be submitted for inclusion in a dissertation in a uniform format and typeset.
- In addition to the individual papers, students must prepare abstract, introduction, discussion, and conclusions sections of the thesis that tie together the individual papers into a unified dissertation.
- A student’s thesis committee might also require the preparation and inclusion of various appendices with the dissertation in support of the papers prepared explicitly for publication.

Graduate Program Background Requirements

All graduate programs in Geophysics require that applicants have a background that includes the equivalent of adequate undergraduate preparation in the following areas:

- Mathematics – Linear Algebra or Linear Systems, Differential Equations, and Computer Programming
- Physics – Classical Mechanics, and Electromagnetism
- Geology – Structural Geology and Stratigraphy
- Geophysics – Courses that include theory and application in three of the following areas: gravity/magnetics, seismic, electrical/ electromagnetics, borehole geophysics, remote sensing, and geodynamics.
- Field experience in the hands-on application of several geophysical methods
- In addition, candidates in the Doctoral program are required to have no less than one year of college-level or two years of high-school-level courses in a single foreign language, or be able to demonstrate fluency in at least one language other than English.

Professors

John H. Bradford, Department Head

Yaoguo Li

Roelof K. Snieder, W.M. Keck Distinguished Professor of Professional Development Education

Ilya D. Tsvankin

Ali Tura

Associate Professors

Thomas M. Boyd, Interim Provost

Brandon Dugan, Baker Hughes Chair in Petrophysics and Borehole Geophysics

Paul C. Sava, C.H. Green Chair of Exploration Geophysics

Jeffrey C. Shragge

Assistant Professors

Ebru Bozdag

Andrei Swidinsky

Whitney Trainor-Guitton

Professors Emeriti

Norman Bleistein

Thomas L. Davis

Frank A. Hadsell

Dave Hale

Alexander A. Kaufman

Kenneth L. Larner

Gary R. Olhoeft

Phillip R. Romig, Jr.

Terence K. Young

Research Assistant Professors

Jyoti Behura

Antoine Guitton

Richard Krahenbuhl

Adjunct Faculty

Bob Basker

Timothy Collett

Gavin P. Hayes

Walter S. Lynn

Morgan Moschetti

Nathaniel Putzig

Bruce VerWest

David J. Wald

Distinguished Senior Scientists

Warren B. Hamilton

Misac N. Nabighian

Courses

GPGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

GPGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

GPGN507. NEAR-SURFACE FIELD METHODS. 3.0 Semester Hrs.

(I) Students design and implement data acquisition programs for all forms of near-surface geophysical surveys. The result of each survey is then modeled and discussed in the context of field design methods. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, even years.

GPGN509. PHYSICAL AND CHEMICAL PROPERTIES AND PROCESSES IN ROCK, SOILS, AND FLUIDS. 3.0 Semester Hrs.

(I) Physical and chemical properties and processes that are measurable with geophysical instruments are studied, including methods of measurement, interrelationships between properties, coupled processes, and processes which modify properties in pure phase minerals and fluids, and in mineral mixtures (rocks and soils). Investigation of implications for petroleum development, minerals extraction, groundwater exploration, and environmental remediation. Prerequisite: none. 3 hours lecture, 3 semester hours.

GPGN511. ADVANCED GRAVITY AND MAGNETIC EXPLORATION. 4.0 Semester Hrs.

(I) Field or laboratory projects of interest to class members; topics for lecture and laboratory selected from the following: new methods for acquiring, processing, and interpreting gravity and magnetic data, methods for the solution of two- and three-dimensional potential field problems, Fourier transforms as applied to gravity and magnetics, the geologic implications of filtering gravity and magnetic data, equivalent distributions, harmonic functions, inversions. Prerequisite: GPGN411. 3 hours lecture, 3 hours lab and field; 4 semester hours.

GPGN519. ADVANCED FORMATION EVALUATION. 3.0 Semester Hrs.

(II) A detailed review of well logging and other formation evaluation methods will be presented, with the emphasis on the imaging and characterization of hydrocarbon reservoirs. Advanced logging tools such as array induction, dipole sonic, and imaging tools will be discussed. The second half of the course will offer in parallel sessions: for geologists and petroleum engineers on subjects such as pulsed neutron logging, nuclear magnetic resonance, production logging, and formation testing; for geophysicists on vertical seismic profiling, cross well acoustics and electro-magnetic surveys. Prerequisite: GPGN419/PEGN419. 3 hours lecture; 3 semester hours.

GPGN520. ELECTRICAL AND ELECTROMAGNETIC EXPLORATION. 4.0 Semester Hrs.

(I) Electromagnetic theory. Instrumentation. Survey planning. Processing of data. Geologic interpretations. Methods and limitations of interpretation. Prerequisite: GPGN302 and GPGN303. 3 hours lecture, 3 hours lab; 4 semester hours. Offered fall semester, odd years.

GPGN521. ADVANCED ELECTRICAL AND ELECTROMAGNETIC EXPLORATION. 4.0 Semester Hrs.

(II) Field or laboratory projects of interest to class members; topics for lecture and laboratory selected from the following: new methods for acquiring, processing and interpreting electrical and electromagnetic data, methods for the solution of two- and three-dimensional EM problems, physical modeling, integrated inversions. Prerequisite: GPGN420 or GPGN520. 3 hours lecture, 3 hours lab; 4 semester hours. Offered spring semester, even years.

GPGN530. APPLIED GEOPHYSICS. 3.0 Semester Hrs.

(II) Introduction to geophysical techniques used in a variety of industries (mining, petroleum, environmental and engineering) in exploring for new deposits, site design, etc. The methods studied include gravity, magnetic, electrical, seismic, radiometric and borehole techniques. Emphasis on techniques and their applications are tailored to student interests. The course, intended for non-geophysics students, will emphasize the theoretical basis for each technique, the instrumentation used and data collection, processing and interpretation procedures specific to each technique so that non-specialists can more effectively evaluate the results of geophysical investigations. Prerequisites: PHGN100, PHGN200, MATH111, GEGN401. 3 hours lecture; 3 semester hours.

GPGN533. GEOPHYSICAL DATA INTEGRATION & GEOSTATISTICS. 3.0 Semester Hrs.

(I) Students will learn the fundamentals of and explore opportunities for further development of geostatistical data integration techniques for subsurface earth modeling. The class will build on probability theory, spatial correlations and geostatistics algorithms for combing data of diverse support and resolution into subsurface models. The emphasis of the material will be on stochastic methods for combining quantitative and qualitative data into many equi-probable realizations. Activities include computer modeling, written exercises, oral team presentations, and a semester project with opportunity to enhance student?s respective research projects. Also, we will read, discuss and implement current research articles the in literature to encourage implementation of state-of-the-art practices and/or highlighting current opportunities for research. 3 hours lecture; 3 semester hours.

GPGN535. GEOPHYSICAL COMPUTING. 3.0 Semester Hrs.
(I) A survey of computer programming skills most relevant to geophysical data processing, visualization and analysis. Skills enhanced include effective use of multiple programming languages, data structures, multicore systems, and computer memory hierarchies. Problems addressed include multidimensional geophysical image processing, geophysical data acquired at scattered locations, finite-difference approximations to partial differential equations, and other computational problems encountered in research by students. Prerequisites: Experience programming in Java, C, C++ or Fortran. 3 hours lecture, 3 credit hours.

GPGN540. MINING GEOPHYSICS. 3.0 Semester Hrs.
(I) Introduction to gravity, magnetic, electric, radiometric and borehole techniques used primarily by the mining industry in exploring for new deposits but also applied extensively to petroleum, environmental and engineering problems. The course, intended for graduate geophysics students, will emphasize the theoretical basis for each technique, the instrumentation used and data collection, processing and interpretation procedures specific to each technique. Prerequisites: GPGN221, GPGN322, MATH111, MATH112, MATH213. 3 hours lecture; 3 semester hours.

GPGN551. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.
(I, II) Students will probe a range of current methodologies and issues in seismic data processing, and discuss their ongoing and planned research projects. Topic areas include: Statics estimation and compensation, deconvolution, multiple suppression, wavelet estimation, imaging and inversion, anisotropic velocity and amplitude analysis, seismic interferometry, attenuation and dispersion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Every student registers for GPGN551 in only the first semester in residence and receives a grade of PRG. The grade is changed to a letter grade after the student's presentation of thesis research. Prerequisite: none. 1 hour seminar; 1 semester hour.

GPGN552. INTRODUCTION TO SEISMOLOGY. 3.0 Semester Hrs.
(I) Introduction to basic principles of elasticity including Hooke?s law, equation of motion, representation theorems, and reciprocity. Representation of seismic sources, seismic moment tensor, radiation from point sources in homogeneous isotropic media. Boundary conditions, reflection/transmission coefficients of plane waves, plane-wave propagation in stratified media. Basics of wave propagation in attenuative media, brief description of seismic modeling methods. Prerequisite: GPGN461. 3 hours lecture; 3 semester hours.

GPGN553. INTRODUCTION TO SEISMOLOGY. 3.0 Semester Hrs.
(II) This course is focused on the physics of wave phenomena and the importance of wave-theory results in exploration and earthquake seismology. Includes reflection and transmission problems for spherical waves, methods of steepest descent and stationary phase, point-source radiation in layered isotropic media, surface and non-geometrical waves. Discussion of seismic modeling methods, fundamentals of wave propagation in anisotropic and attenuative media. Prerequisite: GPGN552. 3 hours lecture; 3 semester hours. Offered spring semester, even years.

GPGN555. INTRODUCTION TO EARTHQUAKE SEISMOLOGY. 3.0 Semester Hrs.
Equivalent with GPGN455,
(II) 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 Earth structure, earthquake locations, depths and mechanisms; understand Earth's tectonics and rheology; establish long-term earthquake histories and forecast future recurrence; and mitigate against seismic hazards. GPGN555 differs from GPGN455 in that the assignments are approximately 20% longer and encompass more challenging questions. GPGN555 is the appropriate course for graduate students and for undergraduates who expect to go on to study earthquake seismology at graduate school. Prerequisites: GPGN320. 3 hours lecture; 3 semester hours.

GPGN558. SEISMIC DATA INTERPRETATION. 3.0 Semester Hrs.
(II) Practical interpretation of seismic data used in exploration for hydro carbons. Integration with other sources of geological and geophysical information. Prerequisite: GPGN461, GEOL501 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours.

GPGN561. SEISMIC DATA PROCESSING I. 3.0 Semester Hrs.
(I) Introduction to basic principles underlying the processing of seismic data for suppression of various types of noise. Includes the rationale for and methods for implementing different forms of gain to data, and the use of various forms of stacking for noise suppression, such as diversity stacking of Vibroseis data, normal-moveout correction and common-midpoint stacking, optimum-weight stacking, beam steering and the stack array. Also discussed are continuous and discrete oneand two-dimensional data filtering, including Vibroseis correlation, spectral whitening, moveout filtering, data interpolation, slant stacking, and the continuous and discrete Radon transform for enhancing data resolution and suppression of multiples and other forms of coherent noise. Prerequisite: GPGN461. 3 hours lecture; 3 semester hours.

GPGN562. SEISMIC DATA PROCESSING II. 3.0 Semester Hrs.
(II) The student will gain understanding of applications of deterministic and statistical deconvolution for wavelet shaping, wavelet compression, and multiple suppression. Both reflection-based and refraction-based statistics estimation and correction for 2-D and 3-D seismic data will be covered, with some attention to problems where subsurface structure is complex. Also for areas of complex subsurface structure, students will be introduced to analytic and interactive methods of velocity estimation. Where the near-surface is complex, poststack and prestack imaging methods, such as layer replacement are introduced to derive dynamic corrections to reflection data. Also discussed are special problems related to the processing of multi-component seismic data for enhancement of shearwave information, and those related to processing of vertical seismic profile data for separation of upgoing and downgoing P- and S-wave arrivals. Prerequisite: GPGN461 and GPGN561. 3 hours lecture; 3 semester hours. Offered spring semester, odd years.

GPGN570. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.
(II) 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. Prerequisites: PHGN200 and MATH225. 2 hours lecture, 2 hours lab; 3 semester hours.

GPGN574. GROUNDWATER GEOPHYSICS. 4.0 Semester Hrs.
(II) Description of world groundwater aquifers. Effects of water saturation on the physical properties of rocks. Use of geophysical methods in the exploration, development and production of groundwater. Field demonstrations of the application of the geophysical methods in the solution of some groundwater problems. Prerequisite: none. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN575. PLANETARY GEOPHYSICS. 3.0 Semester Hrs.
Equivalent with GPGN475,
(I) Of the solid planets and moons in our Solar System, no two bodies are exactly alike. This class will provide an overview of the observed properties of the planets and moons, cover the basic physical processes that govern their evolution, and then investigate how the planets differ and why. The overarching goals are to develop a quantitative understanding of the processes that drive the evolution of planetary surfaces and interiors, and to develop a deeper understanding of the Earth by placing it in the broader context of the Solar System. Prerequisites: Graduate standing. 3 hours lecture; 3 semester hours.

GPGN576. SPECIAL TOPICS IN THE PLANETARY SCIENCES. 1.0 Semester Hr.
(I, II) Students will read and discuss papers on a particular topic in the planetary sciences. The choice of topic will change each semester. The emphasis is on key topics related to the current state and evolution of the solid planets and moons in our solar system. Readings will include both seminal papers and current research on the topic. Students will take turns presenting summaries of the papers and leading the ensuing discussion. Prerequisites: Graduate standing, or senior standing. 1 hour lecture; 1 semester hour. Repeatable for credit.

GPGN581. GRADUATE SEMINAR. 1.0 Semester Hr.
(I, II) Attendance at scheduled weekly Heiland Distinguished Lectures during each semester of enrollment. Students must complete one individual presentation during the graduate program, at an approved public venue, before degree is granted. Every thesis-based MS student in Geophysics and Geophysical Engineering registers each semester in residence in the program and receive 0.0 credit hours until the last semester in residence. For the last semester, 1.0 credit hours and a grade of PRG are awarded with satisfactory attendance and successful completion of individual presentation requirement. 1 hour seminar; 0 or 1 semester hours.

GPGN598. SPECIAL TOPICS IN GEOPHYSICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GPGN599. GEOPHYSICAL INVESTIGATIONS MS. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GPGN605. INVERSION THEORY. 3.0 Semester Hrs.
(II) Introductory course in inverting geophysical observations for inferring earth structure and processes. Techniques discussed include: Monte-Carlo procedures, Marquardt-Levenburg optimization, and generalized linear inversion. In addition, aspects of probability theory, data and model resolution, uniqueness considerations, and the use of a priori constraints are presented. Students are required to apply the inversion methods described to a problem of their choice and present the results as an oral and written report. Prerequisite: MATH225 and knowledge of a scientific programming language. 3 hours lecture; 3 semester hours.

GPGN651. ADVANCED SEISMOLOGY. 3.0 Semester Hrs.
(I) In-depth discussion of wave propagation and seismic processing for anisotropic, heterogeneous media. Topics include influence of anisotropy on plane-wave velocities and polarizations, traveltime analysis for transversely isotropic models, anisotropic velocity-analysis and imaging methods, point-source radiation and Green?s function in anisotropic media, inversion and processing of multicomponent seismic data, shear-wave splitting, and basics of seismic fracture characterization. Prerequisites: GPGN552 and GPGN553. 3 hours lecture; 3 semester hours.

GPGN658. SEISMIC WAVEFIELD IMAGING. 3.0 Semester Hrs.
(I) Seismic imaging is the process that converts seismograms, each recorded as a function of time, to an image of the earth's subsurface, which is a function of depth below the surface. The course emphasizes imaging applications developed from first principles (elastodynamics relations) to practical methods applicable to seismic wavefield data. Techniques discussed include reverse-time migration and migration by wavefield extrapolation, angle-domain imaging, migration velocity analysis and analysis of angle-dependent reflectivity. Students do independent term projects presented at the end of the term, under the supervision of a faculty member or guest lecturer. Prerequisite: none. 3 hours lecture; 3 semester hours.

GPGN660. MATHEMATICS OF SEISMIC IMAGING AND MIGRATION. 3.0 Semester Hrs.
(II) During the past 40 years geophysicists have developed many techniques (known collectively as ?migration?) for imaging geologic structures deep within the Earth?s subsurface. Beyond merely imaging strata, migration can provide information about important physical properties of rocks, necessary for the subsequent drilling and development of oil- and gas-bearing formations within the Earth. In this course the student will be introduced to the mathematical theory underlying seismic migration, in the context of ?inverse scattering imaging theory.? The course is heavily oriented toward problem solving. 3 hours lecture; 3 semester hours. Offered spring semester, odd years.

GPGN681. GRADUATE SEMINAR - PHD. 1.0 Semester Hr.
(I, II) Attendance at scheduled weekly Heiland Distinguished Lectures during each semester of enrollment. Students must complete one individual presentation at an approved, offcampus conference before degree is granted. Every PhD student in Geophysics and Geophysical Engineering registers each semester in residence in the program and receive 0.0 credit hours until the last semester in residence. For the last semester, 1.0 credit hours and a grade of PRG are awarded with satisfactory attendance and successful completion of individual presentation requirement. 1 hour seminar; 1 semester hour.

GPGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GPGN699. GEOPHYSICAL INVESTIGATION-PHD. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GPGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

SYGN501. RESEARCH SKILLS FOR GRADUATE STUDENTS. 1.0 Semester Hr.
(I, II) This course consists of class sessions and practical exercises. The content of the course is aimed at helping students acquire the skills needed for a career in research. The class sessions cover topics such as the choice of a research topic, making a work plan and executing that plan effectively, what to do when you are stuck, how to write a publication and choose a journal for publication, how to write proposals, the ethics of research, the academic career versus a career in industry, time-management, and a variety of other topics. The course is open to students with very different backgrounds; this ensures a rich and diverse intellectual environment. Prerequisite: None. 1 hour lecture; 1 semester hour.

Humanities, Arts, and Social Sciences

Degree Offered

- Master of Science in Natural Resources and Energy Policy (Non-Thesis)

Certificates Offered

- Graduate Certificate in Natural Resources and Energy Policy

Minors Offered

- Minor- A 12 credit-hour minor for graduate students pursuing degrees in other Mines academic units. Please contact either a HASS faculty member with whom you are interested in working or the director of the HASS graduate program. The Graduate Individual Minor must be approved by the student's graduate committee and by the HASS Division.

Program Description

As the 21st century unfolds, individuals, communities, and nations face major challenges in energy, natural resources, and the environment. The Division of Humanities, Arts, and Social Sciences offers a graduate degree entitled Natural Resources and Energy Policy (NREP).

The Division of Humanities, Arts, & Social Sciences offers a graduate degree, the Master of Science in Natural Resources and Energy Policy (NREP).

The multidisciplinary NREP degree provides engineers, scientists, and others interested in energy and natural resources sectors with a range of social science skills and knowledge. Open to new graduates as well as midcareer professionals, NREP graduates will possess critical skills to respond to domestic and global challenges related to natural resources, resource management, and energy policies in the 21st century. The program trains students in quantitative and qualitative methodologies to enable them to understand, analyze, and implement complex solutions in diverse social and political settings around the world. The program is research and writing-intensive with a strong focus on verbal and written communication skills in critical issues facing the extractive industries, natural resource management, and national and global energy.

Through core courses and electives students acquire in-depth knowledge of political risk analysis and mitigation, community outreach and social responsibility, international development, and local and global policymaking,. The degree targets the following jobs: analysts at energy and financial analytics companies; policy, government affairs, risk management, community development, and similar positions in energy, mining, and other engineering companies; local, state, and federal government positions related to energy and resources; and non-profit organizations (advocacy, trade associations, etc.) working on energy, environment, or natural resources.

NREP is a professional degree that requires 30 credit hours: 18 in the core and 12 in electives

Combined Undergraduate/Graduate Degree Programs

Mines students may earn the master's degree as part of CSM's Combined Undergraduate/Graduate program. Students participating in the combined degree program may double count up to 6 semester hours of 400-level course work from their undergraduate course work.

Please note that Mines students interested in pursuing a Combined Undergraduate/Graduate program are encouraged to make an initial contact with the NREP Director after the first semester of their sophomore year for counseling on application procedures, admissions standards, and degree completion requirements.

See "Combined Undergraduate/Graduate Degree Programs" elsewhere in this bulletin for further details.

Admission Requirements

The requirements for admission into HASS Graduate Programs are as follows:

1. An undergraduate degree with a cumulative grade point average (GPA) at or above 3.0 (4.0 scale) or be a CSM undergraduate with a minimum GPA of 3.0 in HASS course work.
2. The GRE is required for most applicants. GRE are waived for current MINES students and (with the NREP Director's approval) can be waived for those with 5+ years of relevant experience. GMAT scores may be used in lieu of the GRE.
3. For students whose native language is not English, Mines requires a minimum TOEFL score of 79 internet-based test (iBT) or 550 paper-based test (PBT). Tests must have been taken within the past two years to be accepted. *If you have completed a university degree program in the United States or in an English speaking country within the previous two years, you do NOT have to submit TOEFL scores.*

Master of Science in Natural Resources & Energy Policy (Non-Thesis)

The multidisciplinary NREP degree aims to train engineers and social scientists in the critical skills needed to respond to domestic and global challenges related to natural resources and energy issues in the 21st century. The program trains students in quantitative and qualitative methods as well as enhancing their skills to critically analyze natural resource, environment, and energy issues and to implement complex solutions in diverse social and political settings. Students engage in research- and writing-intensive assignments with a strong focus on verbal and written communication skills.

Graduates will gain in-depth knowledge of political risk analysis and mitigation, laws and regulations related to the extractive industries and the environment, principles of social responsibility, tools for community outreach and problem-solving, anti-corruption policies, and the politics and processes behind local, national, and global policymaking.

Designed for both early and mid-career professionals, the degree targets the following jobs: policy, government affairs, risk management, community development, social responsibility, and similar positions in energy, environment, and mining companies; local, state, and federal government positions related to energy and resources; and non-profit organizations (advocacy, trade associations, etc.) working on energy and natural resources issues.

NREP is a professional degree that requires 30 credit hours: 18 in the core and 12 in electives. Students are encouraged to pursue internships which may count toward elective credits. Transfer students may apply up to 6 credit hours for courses that meet our requirements.

Required Courses

HASS593	NATURAL RESOURCES & ENERGY POLICY: THEORIES AND PRACTICE	3.0
PEGN530	ENVIRONMENTAL, ENERGY, AND NATURAL RESOURCES LAW	3.0
MNGN590	MECHANICAL EXCAVATION IN MINING	3.0
HASS552	CORRUPTION AND DEVELOPMENT	3.0
HASS550	POLITICAL RISK ASSESSMENT	3.0
ELECT	QUANTITATIVE METHODS ELECTIVE	3.0
Total Semester Hrs		18.0

Approved Quantitative Methods course list:

EBGN590	ECONOMETRICS I	3.0
MATH530	STATISTICAL METHODS I	3.0
MNGN565	MINE RISK MANAGEMENT	3.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0

- With the NREP Graduate Director's approval, students may also take an online graduate-level course.

Approved Electives by Areas of Interest

4 courses (12 credit hours); at least 6 credit hours in HASS. Students may apply up to two 400-level courses (6 credit hours) in areas consistent with the degree and with the Graduate Director's approval. Mines students in the BS/MS program may double-count up to 6 credit hours. Other electives may be approved on a case-by-case basis.

Students are encouraged to focus on one of the following areas of interest and/or to get a Minor in a related discipline, such as Environmental Engineering or Mining. Some courses have prerequisites or are primarily for engineers in those fields; students should check with the professor before taking the course.

International Development and Global Issues

HASS535	INTERNATIONAL DEVELOPMENT	3.0
HASS558	NATURAL RESOURCES AND DEVELOPMENT	3.0
HASS591	ENERGY POLITICS	3.0
HASS592	ENERGY AND SECURITY POLICY	3.0

Energy and Environmental Studies

HASS521	ENVIRONMENTAL PHILOSOPHY	3.0
HASS525	ENVIRONMENTAL COMMUNICATION	3.0
HASS587	ENVIRONMENTAL POLITICS AND POLICY	3.0
HASS588	WATER POLITICS AND POLICY	3.0
HASS591	ENERGY POLITICS	3.0
HASS592	ENERGY AND SECURITY POLICY	3.0
CEEN591	ENVIRONMENTAL PROJECT MANAGEMENT	3.0
CEEN593	ENVIRONMENTAL PERMITTING AND REGULATORY COMPLIANCE	3.0
CEEN573	RECLAMATION OF DISTURBED LANDS	3.0
CEEN574	SOLID WASTE MINIMIZATION AND RECYCLING	3.0
CEEN575	HAZARDOUS WASTE SITE REMEDIATION	3.0
CEEN576	POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE	3.0
CEEN595	ANALYSIS OF ENVIRONMENTAL IMPACT	3.0
EBGN570	ENVIRONMENTAL ECONOMICS	3.0

Mining

CEEN556	MINING AND THE ENVIRONMENT	3.0
CEEN573	RECLAMATION OF DISTURBED LANDS	3.0
MNGN501	REGULATORY MINING LAWS AND CONTRACTS	3.0
MNGN503	MINING TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT	3.0
MNGN510	FUNDAMENTALS OF MINING AND MINERAL RESOURCE DEVELOPMENT	3.0
MNGN540	CLEAN COAL TECHNOLOGY	3.0

Business, Economics, and Energy Analytics

EBGN509	MATHEMATICAL ECONOMICS	3.0
EBGN510	NATURAL RESOURCE ECONOMICS	3.0
EBGN530	ECONOMICS OF INTERNATIONAL ENERGY MARKETS	3.0
EBGN594	TIME-SERIES ECONOMETRICS	3.0
EBGN632	PRIMARY FUELS	3.0
GEOL514	BUSINESS OF ECONOMIC GEOLOGY	3.0
MATH530	STATISTICAL METHODS I	3.0

Courses approved for Quantitative Methods may also be taken as electives

Certificate in Natural Resources and Energy Policy

Designed to be completed in a single semester, or over two semesters for part-time students, the Certificate in Natural Resources & Energy Policy (NREP) is a 12 credit-hour program affiliated with the MS in NREP.

To earn the certificate, students must take four of the six required courses for the Master's program:

HASS593	NATURAL RESOURCES & ENERGY POLICY: THEORIES AND PRACTICE	3.0
PEGN530	ENVIRONMENTAL, ENERGY, AND NATURAL RESOURCES LAW	3.0
MNGN590	MECHANICAL EXCAVATION IN MINING	3.0
HASS552	CORRUPTION AND DEVELOPMENT	3.0
HASS550	POLITICAL RISK ASSESSMENT	3.0
QUANT	QUANTITATIVE METHODS ELECTIVE	

Approved Quantitative Methods list:

EBGN590	ECONOMETRICS I	3.0
MATH530	STATISTICAL METHODS I	3.0
MNGN565	MINE RISK MANAGEMENT	3.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0

Professors

Elizabeth Van Wie Davis

Kenneth Osgood,

Associate Professors

Hussein A. Amery, Division Director

Tina L. Gianquitto

Kathleen J. Hancock

John R. Heilbrunn

Jon A. Leydens

James D. Straker

Assistant Professors

Adrianne Kroepsch

Teaching Professors

Sarah J. Hitt, McBride Honors Program Director

Robert Klimek

Toni Lefton

Sandy Woodson, Faculty Undergraduate Advisor

Teaching Associate Professors

Joseph Horan , Associate Division Director

Jonathan H. Cullison

Paula A. Farca

Cortney E. Holles

Derrick Hudson

Rose Pass

Teaching Assistant Professors

Melanie Brandt

Olivia Burgess

Rachel Osgood

Seth Tucker

Research Assistant Professor

Qin Zhu

Hennebach Visiting Scholar

Shannon Mancus

Professors Emeriti

W. John Cieslewicz

T. Graham Hereford

Barbara M. Olds

Eul-Soo Pang

Anton G. Pegis

Thomas Philipose, University Emeritus Professor

Arthur B. Sacks

Joseph D. Sneed

Associate Professors Emeriti

Betty J. Cannon

Kathleen H. Ochs

Laura J. Pang

Karen B. Wiley

Courses

HASS521. ENVIRONMENTAL PHILOSOPHY AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS521,
Analyzes environmental ethics and philosophy including the relation of philosophical perspectives to policy decision making. Critically examines often unstated ethical and/or philosophical assumptions about the environment and how these may complicate and occasionally undermine productive policies. Policies that may be considered include environmental protection, economic development, and energy production and use. 3 hours seminar; 3 semester hours.

HASS523. ADVANCED SCIENCE COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS523,
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. 3 hours seminar; 3 semester hours.

HASS525. ENVIRONMENTAL COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS525,
(I, II, S) 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 by diverse audiences. 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. 3 lecture hours, 3 semester hours.

HASS535. INTERNATIONAL DEVELOPMENT. 3.0 Semester Hrs.

Equivalent with LAIS535,

(I, II, S) Explores the political economy of current and recent-historical development strategies, models, efforts, and issues in various world regions. The class will focus on Africa, Asia, Eurasia, Latin America, or the Middle East, depending on the semester. 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. Students will explore the roles of governments, companies, organizations, and individuals. Exact topics to be covered will vary with current events and the specific region; topics might include income inequality, the role of national and private energy companies, the impact of globalization, the role of development aid, and concepts of good governance. Students may take the course up to three times, covering different regions. 3 hours lecture; 3 semester hours.

HASS541. AFRICAN DEVELOPMENT. 3.0 Semester Hrs.

Equivalent with LAIS541,

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. 3 hours lecture and discussion; 3 semester hours.

HASS542. NATURAL RESOURCES AND WAR IN AFRICA. 3.0 Semester Hrs.

Equivalent with LAIS542,

Examines the relationship between natural resources and wars in Africa. It begins by discussing the complexity of Africa with its several many languages, peoples, and geographic distinctions. Among the most vexing challenges for Africa is the fact that the continent possesses such wealth and yet still struggles with endemic warfare, which is hypothetically caused by greed and competition over resource rents. Readings are multidisciplinary and draw from policy studies, economics, and political science. Students will acquire an understanding of different theoretical approaches from the social sciences to explain the relationship between abundant natural resources and war in Africa. The course helps students apply the different theories to specific cases and productive sectors. 3 hours lecture and discussion; 3 semester hours.

HASS545. INTERNATIONAL POLITICAL ECONOMY. 3.0 Semester Hrs.

Equivalent with LAIS545,

Introduces students to the field of International Political Economy (IPE) . IPE scholars examine the intersection between economics and politics, with a focus on interactions between states, organizations, and individuals around the world. Students will become familiar with the three main schools of thought on IPE: Realism (mercantilism), Liberalism, and Historical Structuralism (including Marxism and feminism) and will evaluate substantive issues such as the role of international organizations (the World Trade Organization, the World Bank, and the International Monetary Fund), the monetary and trading systems, regional development, international development, foreign aid, debt crises, multinational corporations, and globalization. 3 hours seminar; 3 semester hours.

HASS550. POLITICAL RISK ASSESSMENT. 3.0 Semester Hrs.

Equivalent with LAIS550,

Uses social science analytical tools and readings as well as indices prepared by organizations, such as the World Bank and the International Monetary Fund, to create assessments of the political, social, economic, environmental and security risks that multinational corporations may face as they expand operations around the world. Students will develop detailed political risk reports for specific countries that teams collectively select. Prerequisite: HASS 545 and IPE Minor. 3 hours seminar; 3 semester hours.

HASS552. CORRUPTION AND DEVELOPMENT. 3.0 Semester Hrs.

Equivalent with LAIS552,

Addresses the problem of corruption and its impact on development. Readings are multidisciplinary and include policy studies, economics, and political science. Students will acquire an understanding of what constitutes corruption, how it negatively affects development, and what they, as engineers in a variety of professional circumstances, might do in circumstances in which bribe paying or taking might occur. 3 hours lecture and discussion; 3 semester hours.

HASS558. NATURAL RESOURCES AND DEVELOPMENT. 3.0 Semester Hrs.

Equivalent with LAIS558,

Examines the relationship between natural resources and development. It begins by discussing theories of development and how those theories account for specific choices among resource abundant countries. From the theoretical readings, students examine sector specific topics in particular cases. These subjects include oil and natural gas in African and Central Asian countries; hard rock mining in West Africa and East Asia; gemstone mining in Southern and West Africa; contracting in the extractive industries; and corporate social responsibility. Readings are multidisciplinary and draw from policy studies, economics, and political science to provide students an understanding of different theoretical approaches from the social sciences to explain the relationship between abundant natural resources and development. 3 hours lecture and discussion; 3 semester hours.

HASS560. GLOBAL GEOPOLITICS. 3.0 Semester Hrs.

Equivalent with LAIS560,

Examines geopolitical theories and how they help us explain and understand contemporary developments in the world. Empirical evidence from case studies help students develop a deeper understanding of the interconnections between the political, economic, social, cultural and geographic dimensions of governmental policies and corporate decisions. Prerequisites: any two IPE courses at the 300-level, or one IPE course at the 400 level. 3 hours lecture and discussion; 3 semester hours.

HASS565. SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.

Equivalent with LAIS565,

Provides an introduction to foundational concepts, themes, and questions developed within the interdisciplinary field of science and technology studies (STS). Readings address anthropological understandings of laboratory practice, sociological perspectives on the settling of techno-scientific controversies, historical insights on the development of scientific institutions, philosophical stances on the interactions between technology and humans, and relationships between science and democracy. Students complete several writing assignments, present material from readings and research, and help to facilitate discussion. 3 hours lecture and discussion; 3 semester hours.

HASS586. SCIENCE AND TECHNOLOGY POLICY. 3.0 Semester Hrs.
Equivalent with LAIS586,
Examines current issues relating to science and technology policy in the United States and, as appropriate, in other countries. 3 hours lecture and discussion; 3 semester hours.

HASS587. ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS587,
Explores 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. 3 hours lecture and discussion; 3 semester hours.

HASS588. WATER POLITICS AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS588,
Examines water policies and the political and governmental processes that produce them, as an example of natural resource politics and policy in general. Group discussion and independent research on specific politics and policy issues. Primary but not exclusive focus on the U.S. 3 hours lecture and discussion; 3 semester hours.

HASS590. ENERGY AND SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS590,
(II) The course begins with a brief introduction to global energy production and conservation, focusing on particular case studies that highlight the relationship among energy, society, and community in different contexts. The course examines energy successes and failures wherein communities, governments, and/or energy companies come together to promote socially just and economically viable forms of energy production/conservation. The course also explores conflicts driven by energy development. These case studies are supplemented by the expertise of guest speakers from industry, government, NGOs, and elsewhere. Areas of focus include questioning the forward momentum of energy production, its social and environmental impact, including how it distributes power, resources and risks across different social groups and communities. 3 hours seminar; 3 semester hours.

HASS591. ENERGY POLITICS. 3.0 Semester Hrs.
(I) 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 possibly a few other US states), conducting primary research on the stakeholders and the relevant political outcomes for non-renewables and renewables, making comparisons between the two groups. We will work with energy companies, non-governmental organizations, university and research entities, government representatives, and local activists. 3 lecture hours, 3 semester hours.

HASS592. ENERGY AND SECURITY POLICY. 3.0 Semester Hrs.
(II) Energy and Security Policy is a graduate course that applies a social science lens to understanding the intersections between national and international security concerns and energy. In this course, we will examine these intersections through a case study approach that includes directed readings, such as books and peer-reviewed journal articles, that incorporate student-led discussions and research projects. By exploring various energy security scenarios, such as restricted access to oil and gas, graduate students will gain a comprehensive understanding of the energy-security nexus and the role governments and policies play in enhancing or limiting security. 3 hours lecture, 3 semester hours.

HASS593. NATURAL RESOURCES & ENERGY POLICY: THEORIES AND PRACTICE. 3.0 Semester Hrs.
(I) This course introduces students to the policy-making process, drawing on a variety of theoretical approaches, geographic locations (within the US and in other countries), and resources and energy issues. Coordinated by the NREP Graduate Director, speakers will be from HASS, Economics and Business, Petroleum Engineering, Mining, and other departments with policy expertise, as well as from others who influence and create public and private policy. In the second half of the course, students will conduct original research projects that focus on natural resources and energy, applying theoretical frameworks they have learned from the speakers. 3 lecture hours, 3 semester hours.

HASS598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

HASS599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

HASS601. ACADEMIC PUBLISHING. 2-3 Semester Hr.
Equivalent with LAIS601,
Students will finish this course with increased knowledge of general and discipline - specific writing conversations as well as the ability to use that knowledge in publishing portions of theses or dissertations. Beyond the research article, students will also have the opportunity to learn more about genres such as conference abstracts, conference presentations, literature reviews, and research funding proposals. Prerequisite: Must have completed one full year (or equivalent) of graduate school course work. Variable credit: 2 or 3 semester hours.

HASS698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

HASS699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

HASS707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
Equivalent with LAIS707,
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

LICM501. PROFESSIONAL ORAL COMMUNICATION. 1.0 Semester Hr.

A five-week course which teaches the fundamentals of effectively preparing and presenting messages. "Hands-on" course emphasizing short (5- and 10-minute) weekly presentations made in small groups to simulate professional and corporate communications. Students are encouraged to make formal presentations which relate to their academic or professional fields. Extensive instruction in the use of visuals. Presentations are rehearsed in class two days prior to the formal presentations, all of which are video-taped and carefully evaluated. 1 hour lecture/lab; 1 semester hour.

Mining Engineering

Degrees Offered

- Master of Science in Mining and Earth Systems Engineering (with or without thesis)
- Doctor of Philosophy in Mining and Earth Systems Engineering
- Professional Masters - Mining Engineering and Management (Online Degree)

Program Description

The program has two distinctive, but inherently interwoven specialties.

The **Mining Engineering** area or specialty is predominantly for mining engineers and it is directed towards the traditional mining engineering fields. Graduate work is normally centered around subject areas such as mine planning and development, computer aided mine design, rock mechanics, operations research applied to the mineral industry, environment and sustainability considerations, mine mechanization, mine evaluation, finance and management and similar mining engineering topics.

The **Earth Systems Engineering** area or specialty is designed to be distinctly interdisciplinary by merging the mining engineering fundamentals with civil, geotechnical, environmental or other engineering into advanced study tracks in earth systems, rock mechanics and earth structural systems, underground excavation, and construction systems. This specialty is open for engineers with different sub-disciplinary backgrounds, but interested in working and/or considering performing research in mining, tunneling, excavation and underground construction areas.

Graduate work is normally centered around subject areas such as site characterization, environmental aspects, underground construction and tunneling (including microtunneling), excavation methods and equipment, mechanization of mines and underground construction, environmental and management aspects, modeling and design in geoengineering.

Program Requirements

The Master of Science degree in Mining and Earth Systems Engineering has two options available. Master of Science - Thesis and Master of Science - Non-Thesis.

Thesis Option	
Course work (minimum)	21.0
Research, approved by the graduate committee	9.0
Master's Thesis	
Total Semester Hrs	30.0

Non-Thesis Option	
Course work (minimum) *	30.0

* Six (6) credit hours may be applied towards the analytical report writing, if required.

The Master of Engineering degree (Engineer of Mines) in Mining Engineering includes all the requirements for the M.S. degree, with the sole exception that an “engineering report” is required rather than a Master’s Thesis.

The Doctor of Philosophy degree in Mining and Earth Systems Engineering requires a total of 72 credit hours, beyond the bachelor's degree.

Course work (maximum)	48.0
Research (minimum)	24.0
Total Semester Hrs	72.0

Those with an MSc in an appropriate field may transfer a maximum of 30 credit hours of course work towards the 48 credit hour requirement upon the approval of the advisor and thesis committee. The thesis must be successfully defended before a doctoral committee.

Prerequisites

Students entering a graduate program for the master’s or doctor’s degree are expected to have had much the same undergraduate training as that required at Colorado School of Mines in mining, if they are interested in the traditional mining specialty. Students interested in the Earth Systems engineering specialty with different engineering sub-disciplinary background may also require special mining engineering subjects depending upon their graduate program. Deficiencies if any, will be determined by the Department of Mining Engineering on the basis of students’ education, experience, and graduate study.

For specific information on prerequisites, students are encouraged to refer to a copy of the Mining Engineering Department’s Departmental Guidelines and Regulations (p. 37) for Graduate Students, available from the Mining Engineering Department.

Required Curriculum

Graduate students, depending upon their specialty and background may be required to complete two of the three core courses listed below during their program of study at CSM. These courses are:

MNGN508	ADVANCED ROCK MECHANICS	3.0
MNGN512	SURFACE MINE DESIGN	3.0
MNGN516	UNDERGROUND MINE DESIGN	3.0

In addition, all full-time graduate students are required to register for and attend MNGN625 - Graduate Mining Seminar each semester while in residence, except in the case of extreme circumstances. For these circumstances, consideration will be given on a case-by-case basis by the coordinator or the Department Head. It is expected that part time students participate in MNGN625 as determined by the course coordinator or the Department Head. Although it is mandatory to enroll in MNGN625 each semester, this course will only count as one credit hour for the total program.

Fields of Research

The Mining Engineering Department focuses on the following fundamental areas:

- Geomechanics, Rock Mechanics and Stability of Underground and Surface Excavations
- Computerized Mine Design and Related Applications (including Geostatistical Modeling)
- Advanced Integrated Mining Systems Incorporating Mine Mechanization and Mechanical Mining Systems
- Underground Excavation (Tunneling) and Construction

- Site Characterization and Geotechnical Investigations, Modeling and Design in Geoengineering.
- Rock Fragmentation
- Mineral Processing, Communition, Separation Technology
- Bulk Material Handling

Professional Masters in Mining Engineering and Management

The PM in Mining Engineering and Management is a unique and competitive degree offering that stands alone among graduate mining engineering programs at domestic and international institutions. This new degree does not replace existing graduate programs that focus on technical development and research, but provides a unique choice for students with managerial and business aspirations to obtain an advanced education in the mining and mineral industries. The PM is designed to be delivered both in a traditional classroom setting and as an online degree. Online delivery will give the program a competitive edge by offering the flexible schedule necessary to attract professionals in full-time employment, or others that cannot leave their place of residence.

The PM curriculum content was developed by Mining Engineering faculty based on discussions with the Department’s Industry Advisory Committee, education professionals, and members of the mining industry.

The curriculum includes 12 courses and one independent project, encompassing 33 credit hours (CR). Course content is guided by the vision and values of Mines and the Mining Engineering Department.

MNGN553	PM - MINE DESIGN AND OPERATION PLANNING	3.0
MNGN548	PM - INTEGRATED INFORMATION AND MINE SYSTEMS MANAGEMENT	3.0
MNGN547	PM - GEOLOGY AND MINING	3.0
MNGN558	PM - MINERAL PROCESSING	3.0
MNGN546	PM - MINE HEALTH AND SAFETY	2.0
MNGN562	PM - MINING ENVIRONMENTAL AND SOCIAL RESPONSIBILITY	2.0
MNGN563	PM - WATER WASTE AND MINE CLOSURE	3.0
MNGN551	PM - MINE ACCOUNTING	2.0
MNGN554	PM - MINE FINANCE	2.0
MNGN557	PM - MINERAL ECONOMICS AND POLICY	2.0
MNGN561	PM - PROJECT MANAGEMENT	3.0
MNGN555	PM - MINE INVESTMENT EVALUATION	3.0
MNGN 5XX	INDEPENDENT PROJECT	2.0
Total Semester Hrs		33.0

The program is developed to meet the world’s evolving challenges related to the Earth, Energy and the Environment, and to address the needs of the world’s growing population to recover and conserve the Earth’s resources. The curriculum will confirm the Colorado School of Mines as an internationally recognized leader in engineering education by providing a unique educational experience that collaborates with industry to prepare graduates for leadership in the earth resources industries.

Based on the Faculty’s assessment of the changes in emerging technical, social, and economic factors present in developing a mineral resource, the proposed Colorado School of Mines curriculum will be the product of choice for domestic and international professional education for the mining industry.

Department Head

Priscilla P. Nelson

Professors

Kadri Dagdelen

H. Sebnem Düzgün

Priscilla P. Nelson

M. Ugur Ozbay

Associate Professors

Mark Kuchta

Hugh B. Miller

Masami Nakagawa

Jamal Rostami

Assistant Professors

Elizabeth A. Holley

Rennie Kaunda

Eunhye Kim

Nicole Smith

Professors of Practice

Barbara Filas

Jürgen Brune, Associate Department Head

Robert Reeves

Research Associate Professor

Vilem Petr

Adjunct Faculty

Joseph Cooper

Joseph Culkin

John W. Grubb

Paul Jones

Matt Morris

Andy Schissler

D. Erik Spiller

William R. Wilson

Courses

GOGN501. SITE INVESTIGATION AND CHARACTERIZATION. 3.0 Semester Hrs.

An applications oriented course covering: geological data collection, geophysical methods for site investigation; hydrological data collection; materials properties determination; and various engineering classification systems. Presentation of data in a format suitable for subsequent engineering design will be emphasized. Prerequisite: Introductory courses in geology, rock mechanics, and soil mechanics. 3 hours lecture; 3 semester hours.

GOGN502. SOLID MECHANICS APPLIED TO ROCKS. 3.0 Semester Hrs.

An introduction to the deformation and failure of rocks and rock masses and to the flow of groundwater. Principles of displacement, strain and stress, together with the equations of equilibrium are discussed. Elastic and plastic constitutive laws, with and without time dependence, are introduced. Concepts of strain hardening and softening are summarized. Energy principles, energy changes caused by underground excavations, stable and unstable equilibria are defined. Failure criteria for intact rock and rock masses are explained. Principles of numerical techniques are discussed and illustrated. Basic laws and modeling of groundwater flows are introduced. Prerequisite: Introductory Rock Mechanics. 3 hours lecture; 3 semester hours.

GOGN503. CHARACTERIZATION AND MODELING LABORATORY. 3.0 Semester Hrs.

An applications oriented course covering: Advanced rock testing procedures; dynamic rock properties determination; on-site measurements; and various rock mass modeling approaches. Presentation of data in a format suitable for subsequent engineering design will be emphasized. Prerequisite: Introductory courses in geology, rock mechanics, and soil mechanics. 3 hours lecture; 3 semester hours.

GOGN504. SURFACE STRUCTURES IN EARTH MATERIALS. 3.0 Semester Hrs.

Principles involved in the design and construction of surface structures involving earth materials. Slopes and cuts. Retaining walls. Tailing dams. Leach dumps. Foundations. Piles and piers. Extensive use of case examples. Prerequisites: GOGN501, GOGN502, GOGN503. 3 hours lecture; 3 semester hours.

GOGN505. UNDERGROUND EXCAVATION IN ROCK. 3.0 Semester Hrs.

Components of stress, stress distributions, underground excavation failure mechanisms, optimum orientation and shape of excavations, excavation stability, excavation support design, ground treatment and rock pre-reinforcement, drill and blast excavations, mechanical excavation, material haulage, ventilation and power supply, labor requirements and training, scheduling and costing of underground excavations, and case histories. Prerequisites: GOGN501, GOGN502, GOGN503. 3 hours lecture; 3 semester hours.

GOGN625. GEO-ENGINEERING SEMINAR. 1.0 Semester Hr.

Discussions presented by graduate students, staff, and visiting lectures on research and development topics of general interest. Required of all graduate students in Geo-Engineering every semester, during residence. Prerequisite: Enrollment in Geo-Engineering Program. 1 semester hour upon completion of thesis or residence.

MNGN501. REGULATORY MINING LAWS AND CONTRACTS. 3.0 Semester Hrs.

(I) Basic fundamentals of engineering law, regulations of federal and state laws pertaining to the mineral industry and environment control. Basic concepts of mining contracts. Offered in even numbered years. Prerequisite: Senior or graduate status. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN503. MINING TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT. 3.0 Semester Hrs.

(I, II) The primary focus of this course is to provide students an understanding of the fundamental principles of sustainability and how they influence the technical components of a mine's life cycle, beginning during project feasibility and extending through operations to closure and site reclamation. Course discussions will address a wide range of traditional engineering topics that have specific relevance and impact to local and regional communities, such as mining methods and systems, mine plant design and layout, mine operations and supervision, resource utilization and cutoff grades, and labor. The course will emphasize the importance of integrating social, political, and economic considerations into technical decision-making and problem solving. 3 hours lecture; 3 semester hours.

MNGN504. UNDERGROUND CONSTRUCTION ENGINEERING IN HARD ROCK. 3.0 Semester Hrs.

(II) This course is developed to introduce students to the integrated science, engineering, design and management concepts of engineered underground construction. The course will cover advanced rock engineering in application to underground construction, geological interpretation and subsurface investigations, equipment options and system selection for projects with realistic constraints, underground excavation initial support and final shotcrete/lining design, and approaches to uncertainty evaluation and risk assessment for underground construction projects. Team design projects and presentations will be required. Prerequisites: CEEN513. Co-requisites: GEGN562. 3 hours lecture; 3 semester hours.

MNGN505. ROCK MECHANICS IN MINING. 3.0 Semester Hrs.

(I) 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.

MNGN506. 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 insitu 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.

MNGN507. ADVANCED DRILLING AND BLASTING. 3.0 Semester Hrs.
(I) An advanced study of the theories of rock penetration including percussion, rotary, and rotary percussion drilling. Rock fragmentation including explosives and the theories of blasting rock. Application of theory to drilling and blasting practice at mines, pits, and quarries. Prerequisite: MNGN407. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN508. ADVANCED ROCK MECHANICS. 3.0 Semester Hrs.
Equivalent with MNGN418,
(I, II, S) Analytical and numerical modeling analysis of stresses and displacements induced around engineering excavations in rock. Insitu 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. One additional design project will be assigned to graduate students. Prerequisites: MNGN321. 3 hours lecture; 3 semester hours.

MNGN509. CONSTRUCTION ENGINEERING AND MANAGEMENT. 3.0 Semester Hrs.
Equivalent with GOGN506,
(II) The course will provide content, methods and experience in construction planning and cost estimating, scheduling and equipment performance, contractual delivery systems and relationships, key contract clauses, risk registration and management, and project controls. Special attention will be paid to geotechnical uncertainty and risk, emerging technologies and industry trends, and to ethics and sustainability as applied to construction engineering and management practices. Co-requisites: GEGN562. 3 hours lecture; 3 semester hours.

MNGN510. FUNDAMENTALS OF MINING AND MINERAL RESOURCE DEVELOPMENT. 3.0 Semester Hrs.
Specifically designed for non-majors, the primary focus of this course is to provide students with a fundamental understanding of how mineral resources are found, developed, mined, and ultimately reclaimed. The course will present a wide range of traditional engineering and economic topics related to: exploration and resource characterization, project feasibility, mining methods and systems, mine plant design and layout, mine operations and scheduling, labor, and environmental and safety considerations. The course will emphasize the importance of integrating social (human), political, and environmental issues into technical decision-making and design. 3 hours lecture; 3 semester hours.

MNGN511. MINING INVESTIGATIONS. 2-4 Semester Hr.
(I, II) Investigational problems associated with any important aspect of mining. Choice of problem is arranged between student and instructor. Prerequisite: none. Lecture, consultation, lab, and assigned reading; 2 to 4 semester hours.

MNGN512. 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 estimates, unit operations, equipment selection, final pit determinations, short- and long-range planning, road layouts, dump planning, and cost estimation. Prerequisite: MNGN210. 3 hours lecture; 3 semester hours.

MNGN514. MINING ROBOTICS. 3.0 Semester Hrs.
(I) Fundamentals of robotics as applied to the mining industry. The focus is on mobile robotic vehicles. Topics covered are mining applications, introduction and history of mobile robotics, sensors, including vision, problems of sensing variations in rock properties, problems of representing human knowledge in control systems, machine condition diagnostics, kinematics, and path finding. Prerequisite: CSCI404. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN515. MINE MECHANIZATION AND AUTOMATION. 3.0 Semester Hrs.
This course will provide an in-depth study of the current state of the art and future trends in mine mechanization and mine automation systems for both surface and underground mining, review the infrastructure required to support mine automation, and analyze the potential economic and health and safety benefits. Prerequisite: MNGN312, MNGN314, MNGN316. 2 hours lecture, 3 hours lab; 3 semester hours. Fall of odd years.

MNGN516. 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 (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. Prerequisite: MNGN210. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN517. ADVANCED UNDERGROUND MINING. 3.0 Semester Hrs.
(II) Review and evaluation of new developments in advanced underground mining systems to achieve improved productivity and reduced costs. The major topics covered include: mechanical excavation techniques for mine development and production, new haulage and vertical conveyance systems, advanced ground support and roof control methods, mine automation and monitoring, new mining systems and future trends in automated, high productivity mining schemes. Prerequisite: Underground Mine Design (e.g., MNGN314). 3 hours lecture; 3 semester hours.

MNGN518. ADVANCED BULK UNDERGROUND MINING TECHNIQUES. 3.0 Semester Hrs.
This course will provide advanced knowledge and understanding of the current state-of-the-art in design, development, and production in underground hard rock mining using bulk-mining methods. Design and layout of sublevel caving, block caving, open stoping and blasthole stoping systems. Equipment selection, production scheduling, ventilation design, and mining costs. Prerequisites: MNGN314, MNGN516. 2 hours lecture, 3 hours lab; 3 semester hours. Spring of odd years.

MNGN519. ADVANCED SURFACE COAL MINE DESIGN. 3.0 Semester Hrs.
(II) Review of current manual and computer methods of reserve estimation, mine design, equipment selection, and mine planning and scheduling. Course includes design of a surface coal mine for a given case study and comparison of manual and computer results. Prerequisite: MNGN312, 316, 427. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in odd years.

MNGN520. ROCK MECHANICS IN UNDERGROUND COAL MINING. 3.0 Semester Hrs.
(I) Rock mechanics consideration in the design of room-and-pillar, longwall, and shortwall coal mining systems. Evaluation of bump and outburst conditions and remedial measures. Methane drainage systems. Surface subsidence evaluation. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN522. FLOTATION. 3.0 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.

MNGN523. SELECTED TOPICS. 2-4 Semester Hr.
(I, II) Special topics in mining engineering, incorporating lectures, laboratory work or independent study, depending on needs. This course may be repeated for additional credit only if subject material is different. Prerequisite: none. 2 to 4 semester hours. Repeatable for credit under different titles.

MNGN524. ADVANCED MINE VENTILATION. 3.0 Semester Hrs.
(I) Advanced topics of mine ventilation including specific ventilation designs for various mining methods, ventilation numerical modeling, mine atmosphere management, mine air cooling, prevention and ventilation response to mine fires and explosions, mine dust control. Prerequisites: MNGN424 Mine Ventilation. Lecture and Lab Contact Hours: 3 hours lecture; 3 semester credit hours.

MNGN525. INTRODUCTION TO NUMERICAL TECHNIQUES IN ROCK MECHANICS. 3.0 Semester Hrs.
(I) Principles of stress and infinitesimal strain analysis are summarized, linear constitutive laws and energy methods are reviewed. Continuous and laminated models of stratified rock masses are introduced. The general concepts of the boundary element and finite element methods are discussed. Emphasis is placed on the boundary element approach with displacement discontinui ties, because of its relevance to the modeling of the extraction of tabular mineral bodies and to the mobilization of faults, joints, etc. Several practical problems, selected from rock mechanics and subsidence engineering practices, are treated to demonstrate applications of the techniques. Prerequi site: MNGN321, EGGN320, or equivalent courses, MATH455. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN526. MODELING AND MEASURING IN GEOMECHANICS. 3.0 Semester Hrs.
(II) Introduction to instruments and instrumen tation systems used for making field measurements (stress, convergence, deformation, load, etc.) in geomechanics. Techniques for determining rock mass strength and deformability. Design of field measurement programs. Interpretation of field data. Development of predictive models using field data. Intro duction to various numerical techniques (boundary element, finite element, FLAC, etc.) for modeling the behavior of rock structures. Demonstration of concepts using various case studies. Prerequisite: Graduate standing. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in odd years.

MNGN527. THEORY OF PLATES AND SHELLS. 3.0 Semester Hrs.
Classical methods for the analysis of stresses in plate type structure are presented first. The stiffness matrices for plate element will be developed and used in the finite element method of analysis. Membrane and bending stresses in shells are derived. Application of the theory to tunnels, pipes, pressures vessels, and domes, etc., will be included. Prerequisites: EGGN320. 3 hours lecture; 3 credit hours.

MNGN528. MINING GEOLOGY. 3.0 Semester Hrs.
(I) Role of geology and the geologist in the development and production stages of a mining operation. Topics addressed: mining operation sequence, mine mapping, drilling, sampling, reserve estimation, economic evaluation, permitting, support functions. Field trips, mine mapping, data evaluation, exercises and term project. Prerequisite: GEGN401 or GEGN405. 2 hours lecture/seminar, 3 hours laboratory: 3 semester hours. Offered in even years.

MNGN529. URANIUM MINING. 2.0 Semester Hrs.
(I) Overview and introduction to the principles of uranium resource extraction and production. All aspects of the uranium fuel cycle are covered, including the geology of uranium, exploration for uranium deposits, mining, processing, environmental issues, and health and safety aspects. A lesser emphasis will be placed on nuclear fuel fabrication, nuclear power and waste disposal.

MNGN530. INTRODUCTION TO MICRO COMPUTERS IN MINING. 3.0 Semester Hrs.
(I) General overview of the use of PC based micro computers and software applications in the mining industry. Topics include the use of: database, CAD, spreadsheets, computer graphics, data acquisition, and remote communications as applied in the mining industry. Prerequisite: Any course in computer programming. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN536. OPERATIONS RESEARCH TECHNIQUES IN THE MINERAL INDUSTRY. 3.0 Semester Hrs.
Analysis of exploration, mining, and metallurgy systems using statistical analysis. Monte Carlo methods, simulation, linear programming, and computer methods. Prerequisite: MNGN433. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in even years.

MNGN538. GEOSTATISTICAL ORE RESERVE ESTIMATION. 3.0 Semester Hrs.
(I) Introduction to the application and theory of geostatistics in the mining industry. Review of elementary statistics and traditional ore reserve calculation techniques. Presentation of fundamental geostatistical concepts, including: variogram, estimation variance, block variance, kriging, geostatistical simulation. Emphasis on the practical aspects of geostatistical modeling in mining. Prerequisite: MATH323 or equivalent course in statistics; graduate or senior status. 3 hours lecture; 3 semester hours.

MNGN539. ADVANCED MINING GEOSTATISTICS. 3.0 Semester Hrs.
(II) Advanced study of the theory and application of geostatistics in mining engineering. Presentation of state-of-the-art geostatistical concepts, including: robust estimation, nonlinear geostatistics, disjunctive kriging, geostatistical simulation, computational aspects. This course includes presentations by many guest lecturers from the mining industry. Emphasis on the development and application of advanced geostatistical techniques to difficult problems in the mining industry today. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN540. CLEAN COAL TECHNOLOGY. 3.0 Semester Hrs.
(I, II) Clean Energy - Gasification of Carbonaceous Materials - including coal, oil, gas, plastics, rubber, municipal waste and other substances. This course also covers the process of feedstock preparation, gasification, cleaning systems, and the output energy blocks along with an educational segment on CO products. These output energy blocks include feedstock to electrical power, feedstock to petroleum liquids, feedstock to pipeline quality gas. The course covers co- product development including urea, fertilizers, CO2 extraction/sequestration and chemical manufacturing.

MNGN545. 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.

MNGN546. PM - MINE HEALTH AND SAFETY. 2.0 Semester Hrs.
(I, II, S) This course describes the principles of providing a safe and healthy work environment, focusing on the cultural and behavioral elements. Realigning long-learned human behaviors into a culture of safety and health consciousness is a significant management challenge, particularly in the developing world. Learning emphasis will be balanced among fundamentals, future trends, but risk will be a driver among discussion topics. Health and safety will be discussed in the context of the project cycle and also how the culture can transcend the workplace through mine employees to their families, neighbors and communities. 2 hours lecture; 2 semester hours.

MNGN547. PM - GEOLOGY AND MINING. 3.0 Semester Hrs.
(I, II, S) This course presents the relationship between geology and mining including the genesis of ore deposits, exploration, geochemistry, resource assessment, and mine planning. The relationship between the risks associated with reserve estimates and project finance are discussed. 3 hours lecture; 3 semester hours.

MNGN548. PM - INTEGRATED INFORMATION AND MINE SYSTEMS MANAGEMENT. 3.0 Semester Hrs.
(I, II, S) This course presents facilities external to the mine that are necessary to support and maintain mining and waste handling operations, gather, store, and evaluate operating and maintenance databases. Focus will be on systems integration, emerging trends, automation, internet of things (IoT), managing bid data systems, cyber security, sensors, and data evaluation. 3 hours lecture; 3 semester hours.

MNGN549. MARINE MINING SYSTEMS. 3.0 Semester Hrs.
(I) Define interdisciplinary marine mining systems and operational requirements for the exploration survey, sea floor mining, hoisting, and transport. Describe and design components of deep-ocean, manganese-nodule mining systems and other marine mineral extraction methods. Analyze dynamics and remote control of the marine mining systems interactions and system components. Describe the current state-of-the-art technology, operational practice, trade-offs of the system design and risk. Prerequisite: EGGN351, EGGN320, GEOC408. 3 hours lecture; 3 semester hours. Offered alternate even years.

MNGN550. NEW TECHNIQUES IN MINING. 3.0 Semester Hrs.
(II) Review of various experimental mining procedures, including a critical evaluation of their potential applications. Mining methods covered include deep sea nodule mining, in situ gassification of coal, in situ retorting of oil shale, solution mining of soluble minerals, in situ leaching of metals, geothermal power generation, oil mining, nuclear fragmentation, slope caving, electro-thermal rock penetration and fragmentation. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN551. PM - MINE ACCOUNTING. 2.0 Semester Hrs.
(I, II, S) This course presents basic principles of accounting for mine engineers and managers. The preparation, content and analysis of financial statements and balance sheets from a managerial perspective are presented. Cost and accrual accounting for mine projects and operations is covered. Accounting standards in the U.S. and internationally are discussed. Mandatory financial reporting requirements for corporate entities are included in the course. 2 hours lecture; 2 semester hours.

MNGN552. 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. 3 hours lecture, 3 semester hours. Offered in spring.

MNGN553. PM - MINE DESIGN AND OPERATION PLANNING. 3.0 Semester Hrs.
(I, II, S) This course provides an overview of mine design and operating fundamentals with a focus on the emerging trends that will influence the mining industry. Topics provide an overarching significance to social, environmental, and sustainable factors during the design and operation of underground and surface mine planning. 3 hours lecture; 3 semester hours.

MNGN554. PM - MINE FINANCE. 2.0 Semester Hrs.
(I, II, S) This course applies the basic principles and concepts of financing in the mining industry. All methods of accessing capital for U.S. and international mining projects and operations will be presented. Asset and cash management throughout the mine life cycle will be discussed. Approaches to mergers and acquisitions, dividend policy and other financial decisions will be examined. Financial ratios, auditing and other financial controls will be taught. 2 hours lecture; 2 semester hours.

MNGN555. PM - MINE INVESTMENT EVALUATION. 3.0 Semester Hrs.
(I, II, S) This course provides an education in the evaluation of mine capital investments applying the principles of time value of money to after-tax cash flows. Implications of taxes, sustainability funding and debt financing are included. Methods of cost estimation for capital and operating budgets for feasibility studies are taught. The required content of feasibility studies at varying levels of detail is discussed. World standards for resource and reserve determination and public reporting requirements are presented. Methods for sensitivity analysis and real options analysis of mine capital investments are demonstrated. 3 hours lecture; 3 semester hours.

MNGN556. MINE WATER AND ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with CEEN556,
(I) This course will cover core aspects of mine water and mining geotechnics. The main topics to be covered relate to surface and groundwater flow along open pits and underground excavations, tailings and impoundments, mine spoils and waste rock, reclamation and closure. Course emphasizes leadership, teamwork, communication, and creative problem solving skills through the use of case examples, homework, and exams which emphasize typical water and geotechnical problems relevant to the mining industry. Prerequisite: CHGN121, CHGN122. 3 hours lecture, 3 semester hours.

MNGN557. PM - MINERAL ECONOMICS AND POLICY. 2.0 Semester Hrs.
(I, II, S) This course explores the determinants of demand for minerals and the factors that change that demand. The course covers sources of supply - primary, secondary and recycling for mineral commodities. The interaction of supply and demand and the impact on mineral markets is discussed. Public policy as it applies to taxation, economic development and sustainability is presented in both historical and future perspectives. 2 hours lecture; 2 semester hours.

MNGN558. PM - MINERAL PROCESSING. 3.0 Semester Hrs.
(I, II, S) This course presents the fundamentals for devising and specifying mineral processing systems to handle and beneficiate ores into salable concentrates. Ore sampling, testing programs, evaluations, and presentation methods are discussed. Emphasis is made to water and energy requirements, tailings management, and mill development from concept, construction, and operations. 3 hours lecture; 3 semester hours.

MNGN559. MECHANICS OF PARTICULATE MEDIA. 3.0 Semester Hrs.
(1) This course allows students to establish fundamental knowledge of quasi-static and dynamic particle behavior that is beneficial to interdisciplinary material handling processes in the chemical, civil, materials, metallurgy, geophysics, physics, and mining engineering. Issues of interst are the definition of particl size and size distribution, particle shape, nature of packing, quasi-static behavior under different external loading, particle collisions, kinetic theoretical modeling of particulate flows, molecular dynamic simulations, and a brief introduction of solid-fluid two-phase flows. Prerequisite: none. 3 hours lecture; 3 semester hours. Fall semesters, every other year.

MNGN560. INDUSTRIAL MINERALS PRODUCTION. 3.0 Semester Hrs.
(II) This course describes the engineering principles and practices associated with quarry mining operations related to the cement and aggregate industries. The course will cover resource definition, quarry planning and design, extraction, and processing of minerals for cement and aggregate production. Permitting issues and reclamation, particle sizing and environmental practices, will be studied in depth.

MNGN561. PM - PROJECT MANAGEMENT. 3.0 Semester Hrs.
(I, II, S) This course covers project management from major mine construction projects to business improvement projects. Project organization, delivery methods, controls and other aspects of managing projects big and small will be included. Methods for creating improvement results, managing risk, decision-making under conditions of uncertainty and optimizing mining processes will be discussed extensively. Strategies for resolving conflicts that occur in business will be taught. 3 hours lecture; 3 semester hours.

MNGN562. PM - MINING ENVIRONMENTAL AND SOCIAL RESPONSIBILITY. 2.0 Semester Hrs.
(I, II, S) This course describes the fundamentals of mine environmental and social evaluations and controls, including mine permitting, compliance, impact assessment and analysis and the development of effective environmental and social management systems. The course will stress the execution of these elements in a culturally appropriate manner and the risk to project continuity and corporate reputation if these fundamentals are mishandled. Sustainability and project life cycle aspects will be integrated throughout the course. 2 hours lecture; 2 semester hours.

MNGN563. PM - WATER WASTE AND MINE CLOSURE. 3.0 Semester Hrs.
(I, II, S) The course addresses the fundamentals and future trends in water and waste management and the design and implementation of mine closure techniques. Emphasis will be placed on the environmental, social, and cost control risks. Topics covered include: 1) water supply, disposal and treatment, 2) site-wide water management, 3) mine waste rock management, 4) process waste and tailings management, 5) solid, hazardous and medical waste disposal, 6) closure design (conceptual to construction-ready), and 7) post-closure elements. The importance of effective water and waste management practices, as well as integrating closure planning techniques into engineering designs, will be stressed throughout the project life cycle. 3 hours lecture; 3 semester hours.

MNGN565. MINE RISK MANAGEMENT. 3.0 Semester Hrs.
(II) Fundamentals of identifying, analyzing, assessing and treating risks associated with the feasibility, development and operation of mines. Methodologies for identifying, assessing and treating risks will be presented and practiced in case studies and exercises. Concepts and principles for analyzing risks will be demonstrated and practiced utilizing deterministic and stochastic models, deductive models, decision trees and other applicable principles. 3 hours lecture; 3 semester hours.

MNGN570. 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.

MNGN575. HEAT MINING. 3.0 Semester Hrs.
(I) Heat Mining focuses on identifying available sub-surface heat sources. Heat trapped in crystalline rock deep underground is available by engineering an artificial geothermal system. Hot geothermal fluid, heat generated by underground coal fire and hot water trapped in abandoned underground mine are some of other examples. We will discuss how to find them, how to estimate them, and how to extract and convert them to a usable energy form. The concept of sustainable resource development will be taught as the foundation of heat mining. Prerequisites: None. 3 hours lecture; 3 semester hours.

MNGN585. MINING ECONOMICS. 3.0 Semester Hrs.
(I) Advanced study in mine valuation with emphasis on revenue and cost aspects. Topics include price and contract consideration in coal, metal and other commodities; mine capital and operating cost estimation and indexing; and other topics of current interest. Prerequisite: MNGN427 or EBGN504 or equivalent. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN590. MECHANICAL EXCAVATION IN MINING. 3.0 Semester Hrs.

(II) This course provides a comprehensive review of the existing and emerging mechanical excavation technologies for mine development and production in surface and underground mining. The major topics covered in the course include: history and development of mechanical excavators, theory and principles of mechanical rock fragmentation, design and performance of rock cutting tools, design and operational characteristics of mechanical excavators (e.g. continuous miners, roadheaders, tunnel boring machines, raise drills, shaft borers, impact miners, slotters), applications to mine development and production, performance prediction and geotechnical investigations, costs versus conventional methods, new mine designs for applying mechanical excavators, case histories, future trends and anticipated developments and novel rock fragmentation methods including water jets, lasers, microwaves, electron beams, penetrators, electrical discharge and sonic rock breakers. Prerequisite: Senior or graduate status. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN598. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MNGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MNGN625. GRADUATE MINING SEMINAR. 1.0 Semester Hr.

(I, II) Discussions presented by graduate students, staff, and visiting lecturers on research and development topics of general interest. Required of all graduate students in mining engineering every semester during residence. 1 semester hour upon completion of thesis or residence.

MNGN698. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MNGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MNGN700. GRADUATE ENGINEERING REPORTMASTER OF ENGINEERING. 1-6 Semester Hr.

(I, II) Laboratory, field, and library work for the Master of Engineering report under supervision of the student?s advisory committee. Required of candidates for the degree of Master of Engineering. Variable 1 to 6 hours. Repeatable for credit to a maximum of 6 hours.

MNGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Petroleum Engineering

Degrees Offered

- Professional Masters in Petroleum Reservoir Systems
- Master of Engineering (Petroleum Engineering)
- Master of Science (Petroleum Engineering)
- Doctor of Philosophy (Petroleum Engineering)

Program Description

The Petroleum Engineering Department offers students a choice of a Master of Science (MS) degree or a Master of Engineering (ME) degree. For the MS degree, a thesis is required in addition to course work. For the ME degree, no thesis is required, but the course work requirement is greater than that for the MS degree. The Petroleum Engineering Department also offers Petroleum Engineering (PE) undergraduate students the option of a Combined Undergraduate/Graduate Program. This is an accelerated program that provides the opportunity for PE students to get a head start on their graduate education.

Applications from students having a MS in Petroleum Engineering, or in another complimentary discipline, will be considered for admission to the Doctor of Philosophy (Ph.D.) program. To obtain the Ph.D. degree, a student must demonstrate unusual competence, creativity, and dedication in the degree field. In addition to extensive course work, a dissertation is required for the Ph.D. degree.

Applying for Admission

All graduate applicants must have taken core engineering, math and science courses before applying to graduate school. For the Colorado School of Mines this would be 3 units of Calculus, 2 units of Chemistry with Quantitative Lab, 2 units of Physics, Differential Equations, Statics, Fluid Mechanics, Thermodynamics and Mechanics of Materials. To apply for admission, follow the procedure outlined in the general section of this catalog. Three letters of recommendation must accompany the application. The Petroleum Engineering Department requires the general test of the Graduate Record Examination (GRE) for applicants to all degree levels.

Applicants for the Master of Science, Master of Engineering, and Professional Masters in Petroleum Reservoir Systems programs should have a minimum score of 155 or better and applicants for the Ph.D. program are expected to have 159 or better on the quantitative section of the GRE exam, in addition to acceptable scores in the verbal and analytical sections. The GPA of the applicant must be 3.0 or higher. The graduate application review committee determines minimum requirements accordingly, and these requirements may change depending on the application pool for the particular semester. The applicants whose native language is not English are also expected to provide satisfactory scores on the TOEFL (Test of English as a Foreign Language) exam as specified in the general section of this catalog.

Required Curriculum

A student in the graduate program selects course work by consultation with the Faculty Advisor and with the approval of the graduate committee. Course work is tailored to the needs and interests of the student. Students who do not have a BS degree in petroleum engineering must take deficiency courses as required by the department as soon as possible in their graduate programs. Depending on the applicant's undergraduate degree, various basic undergraduate petroleum engineering and geology courses will be required. These deficiency courses are not counted towards the graduate degree; nonetheless, the student is expected to pass the required courses and the grades received in these courses are included in the GPA. Not passing these courses can jeopardize the student's continuance in the graduate program. It is desirable for students with deficiencies to complete the deficiencies or course work within the first two semesters of arrival to the program or as soon as possible with the approval of their advisor.

All PE graduate students are required to complete 3 credit hours of course work in writing, research, or presentation intensive classes, such as PEGN681, LICM501, SYGN501, and SYGN600, as agreed to by their graduate advisor.

Fields of Research

Current fields of research include:

- Rock and fluid properties, phase behavior, and rock mechanics
- Geomechanics
- Formation evaluation, well test analysis, and reservoir characterization
- Oil recovery processes
- IOR/EOR Methods
- Naturally fractured reservoirs
- Analytical and numerical modeling of fluid flow in porous media
- Pore-scale modeling and flow in nanopores
- Development of unconventional oil and gas plays
- Geothermal energy
- Gas Hydrates
- Completion and stimulation of wells
- Horizontal and multilateral wells
- Multi-stage fracturing of horizontal wells
- Drilling management and rig automation
- Fluid flow in wellbores and artificial lift
- Drilling mechanics, directional drilling,
- Extraterrestrial drilling
- Ice coring and drilling
- Bit vibration analysis, tubular buckling and stability, wave propagation in drilling tubulars
- Laser technology in penetrating rocks
- Environment, health, and safety in oil and gas industry

Research projects may involve professors and graduate students from other disciplines. Projects may include off-campus laboratories, institutes, and other resources.

The Petroleum Engineering Department houses a research institute, two research centers, and two consortia.

Research Institute

- Unconventional Natural Gas and Oil Institute (UNGI)

Research Centers

- Marathon Center of Excellence for Reservoir Studies (MCERS)
- Center for Earth Mechanics, Materials, and Characterization (CEMMC)

Research Consortia

- Fracturing, Acidizing, Stimulation Technology (FAST) Consortium.
- Unconventional Reservoir Engineering Project (UREP) Consortium.
- Petrophysics of Reservoir Sediments: Organics, Clay, Sand and Shale (OCLASSH) Consortium.

Special Features

In the exchange programs with the Petroleum Engineering Departments of the Mining University of Leoben, Austria, Technical University in Delft, Holland, and the University of Adelaide, Australia, a student may spend one semester abroad during graduate studies and receive full transfer of credit back to Colorado School of Mines with prior approval of the Petroleum Engineering Department at Colorado School of Mines.

In the fall of 2012, the new Petroleum Engineering building, Marquez Hall, was opened. The new home for the Petroleum Engineering Department is a prominent campus landmark, showcasing Mines' longstanding strengths in its core focus areas and our commitment to staying at the forefront of innovation. The new building is designed using aggressive energy saving strategies and LEED certified. Marquez Hall is the first building on the Colorado School of Mines Campus that is funded entirely by donations.

The Petroleum Engineering Department enjoys strong collaboration with the Geology and Geological Engineering Department and Geophysics Department at Colorado School of Mines. Courses that integrate the faculty and interests of the three departments are taught at the undergraduate and graduate levels.

The department is close to oil and gas field operations, oil companies and laboratories, and geologic outcrops of producing formations. There are many opportunities for summer and part-time employment in the oil and gas industry.

Each summer, several graduate students assist with the field sessions designed for undergraduate students. The field sessions in the past several years have included visits to oil and gas operations in Alaska, Canada, Southern California, the Gulf Coast, the Northeast US, the Rocky Mountain regions, and western Colorado.

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.

Program Requirements

Professional Masters in Petroleum Reservoir Systems

Minimum 36 hours of course credit

Master of Engineering

Minimum 36 hours of course credit

Master of Science

Minimum 36 hours, of which no less than 12 credit hours earned by research and 24 credit hours by course work

Combined Undergraduate/Graduate Program

The same requirements as Master of Engineering or Master of Science after the student is granted full graduate status. Students in the Combined Undergraduate/Graduate Program may fulfill part of the requirements of their graduate degree by including up to 6 credit hours of undergraduate course credits upon approval of the department.

Doctor of Philosophy

Minimum 90 credit hours beyond the bachelor's degree of which no less than 30 credit hours earned by research, or minimum 54 credit hours beyond the Master's degree of which no less than 30 credit hours earned by research.

The Petroleum Engineering, Geology and Geological Engineering, and the Geophysics Departments share oversight for the **Professional Masters in Petroleum Reservoir Systems** program through a committee consisting of one faculty member from each department. Students gain admission to the program by application to any of the three sponsoring departments. Students are administered by that department into which they first matriculate. A minimum of 36 credit hours of course credit is required to complete the Professional Masters in Petroleum Reservoir Systems program. Up to 9 credits may be earned by 400 level courses. All other credits toward the degree must be 500 level or above. At least 9 hours must consist of:

GEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	3.0
or PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	
Select one of the following:		3.0
GPGN/PEGN419	INTRODUCTION TO FORMATION EVALUATION AND WELL LOGGING	
GPGN/PEGN519	ADVANCED FORMATION EVALUATION	
Select one of the following:		3.0
GEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
or GPGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
or PEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
GEGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	
or GPGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	
or PEGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	
Total Semester Hrs		9.0

Also 9 additional hours must consist of one course each from the 3 participating departments. The remaining 18 hours may consist of graduate courses from any of the 3 participating departments, or other courses approved by the committee. Up to 6 hours may consist of independent study, including an industry project.

Candidates for the non-thesis **Master of Engineering** degree must complete a minimum of 36 hours of graduate course credit. At least 18 of the credit hours must be from the Petroleum Engineering Department. Up to 12 graduate credit hours can be transferred from another institution, and up to 9 credit hours of senior-level courses may be applied to the degree. All courses must be approved by the student's advisor and the department head. No graduate committee is required. No more than six credit hours can be earned through independent study.

Candidates for the **Master of Science** degree must complete at least 24 graduate credit hours of course work, approved by the candidate's graduate committee, and a minimum of 12 hours of research credit. At least 12 of the course credit hours must be from the Petroleum Engineering Department. Up to 9 credit hours may be transferred from another institution. Up to 9 credit hours of senior-level courses may be applied to the degree. For the MS degree, the student must demonstrate ability to observe, analyze, and report original scientific research. For other requirements, refer to the general instructions of the Graduate School (p. 7) in this bulletin.

The requirements for the **Combined Undergraduate/Graduate Program** are defined in the section of this Bulletin titled “Graduate Degrees and Requirements—V. Combined Undergraduate/Graduate Programs.” After the student is granted full graduate status, the requirements are the same as those for the non-thesis Master of Engineering or thesis-based Master of Science degree, depending to which program the student was accepted. The Combined Undergraduate/Graduate Program allows students to fulfill part of the requirements of their graduate degree by including up to 6 credit hours of their undergraduate course credits upon approval of the department. The student must apply for the program by submitting an application through the Graduate School before the first semester of their Senior year. For other requirements, refer to the general directions of the Graduate School (p. 7) in this bulletin.

A candidate for the **Ph.D.** must complete at least 60 hours of course credit and a minimum of 30 credit hours of research beyond the Bachelor’s degree or at least 24 hours of course credit and a minimum of 30 credit hours of research beyond the Master’s degree. The credit hours to be counted toward a Ph.D. are dependent upon approval of the student’s thesis committee. Students who enter the Ph.D. program with a Bachelor’s degree may transfer up to 33 graduate credit hours from another institution with the approval of the graduate advisor. Students who enter the Ph.D. program with a master’s degree may transfer up to 45 credit hours of course and research work from another institution upon approval by the graduate advisor. Ph.D. students must complete a minimum of 12 credit hours of their required course credit in a minor program of study. The student’s faculty advisor, thesis committee, and the department head must approve the course selection. Full-time Ph.D. students must satisfy the following requirements for admission to candidacy within the first two calendar years after enrolling in the program:

1. have a thesis committee appointment form on file,
2. complete all prerequisite courses successfully,
3. demonstrate adequate preparation for and satisfactory ability to conduct doctoral research by successfully completing a series of written and/or oral examinations and fulfilling the other requirements of their graduate committees as outlined in the department's graduate handbook.

Failure to fulfill these requirements within the time limits specified above may result in immediate mandatory dismissal from the Ph.D. program according to the procedure outlined in the section of this Bulletin titled “General Regulations—Unsatisfactory Academic Performance—Unsatisfactory Academic Progress Resulting in Probation or Discretionary Dismissal.” For other requirements, refer to the general directions of the Graduate School (p. 7) in this bulletin and/or the Department's Graduate Student Handbook.

Professors

Erdal Ozkan, Professor and Department Head, "Mick" Merelli/Cimarex Energy Distinguished Chair

Ramona M. Graves, Dean, College of Earth Resource Sciences and Engineering

Hossein Kazemi, Chesebro' Distinguished Chair

Azra N.Tutuncu, Harry D. Campbell Chair

Manika Prasad

Yu-Shu Wu, CMG Chair

Associate Professors

Alfred W. Eustes III

Jennifer Miskimins, Associate Department Head

Jorge H. B. Sampaio Jr.

Xiaolong Yin

Assistant Professors

Luis Zerpa

Teaching Professor

Linda A. Battalora

Teaching Associate Professors

Mansur Ermila

Carrie J. McClelland

Mark G. Miller

Teaching Assistant Professor

Elio S. Dean

Research Associate Professor

Philip H. Winterfeld

Adjunct Professor

William W. Fleckenstein

Professor Emeritus

Craig W. Van Kirk

Bill Scoggins, President Emeritus

Associate Professor Emeritus

Richard Christiansen

Courses

PEGN501. APPLICATIONS OF NUMERICAL METHODS TO PETROLEUM ENGINEERING. 3.0 Semester Hrs.

The course will solve problems of interest in Petroleum Engineering through the use of spreadsheets on personal computers and structured FORTRAN programming on PCs or mainframes. Numerical techniques will include methods for numerical quadrature, differentiation, interpolation, solution of linear and nonlinear ordinary differential equations, curve fitting and direct or iterative methods for solving simultaneous equations. Prerequisites: PEGN414 and PEGN424. 3 hours lecture; 3 semester hours.

PEGN502. ADVANCED DRILLING FLUIDS. 3.0 Semester Hrs.

The physical properties and purpose of drilling fluids are investigated. Emphasis is placed on drilling fluid design, clay chemistry, testing, and solids control. Prerequisite: PEGN311. 2 hours lecture, 3 hours lab; 3 semester hours.

PEGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

PEGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

PEGN505. HORIZONTAL WELLS: RESERVOIR AND PRODUCTION ASPECTS. 3.0 Semester Hrs.

This course covers the fundamental concepts of horizontal well reservoir and production engineering with special emphasis on the new developments. Each topic covered highlights the concepts that are generic to horizontal wells and draws attention to the pitfalls of applying conventional concepts to horizontal wells without critical evaluation. There is no set prerequisite for the course but basic knowledge on general reservoir engineering concepts is useful. 3 hours lecture; 3 semester hours.

PEGN506. ENHANCED OIL RECOVERY METHODS. 3.0 Semester Hrs.

Enhanced oil recovery (EOR) methods are reviewed from both the qualitative and quantitative standpoint. Recovery mechanisms and design procedures for the various EOR processes are discussed. In addition to lectures, problems on actual field design procedures will be covered. Field case histories will be reviewed. Prerequisite: PEGN424. 3 hours lecture; 3 semester hours.

PEGN507. INTEGRATED FIELD PROCESSING. 3.0 Semester Hrs.

Integrated design of production facilities covering multistage separation of oil, gas, and water, multiphase flow, oil skimmers, natural gas dehydration, compression, crude stabilization, petroleum fluid storage, and vapor recovery. Prerequisite: PEGN411. 3 hours lecture; 3 semester hours.

PEGN508. ADVANCED ROCK PROPERTIES. 3.0 Semester Hrs.

Application of rock mechanics and rock properties to reservoir engineering, well logging, well completion and well stimulation. Topics covered include: capillary pressure, relative permeability, velocity effects on Darcy?s Law, elastic/mechanical rock properties, subsidence, reservoir compaction, and sand control. Prerequisites: PEGN423 and PEGN426. 3 hours lecture; 3 semester hours.

PEGN511. ADVANCED THERMODYNAMICS AND PETROLEUM FLUIDS PHASE BEHAVIOR. 3.0 Semester Hrs.

Essentials of thermodynamics for understanding the phase behavior of petroleum fluids such as natural gas and oil. Modeling of phase behavior of single and multi-component systems with equations of states with a brief introduction to PVT laboratory studies, commercial PVT software, asphaltenes, gas hydrates, mineral deposition, and statistical thermodynamics. Prerequisites: PEGN310 and PEGN305 or equivalent. 3 hours lecture; 3 semester hours.

PEGN512. ADVANCED GAS ENGINEERING. 3.0 Semester Hrs.

The physical properties and phase behavior of gas and gas condensates will be discussed. Flow through tubing and pipelines as well as through porous media is covered. Reserve calculations for normally pressured, abnormally pressured and water drive reservoirs are presented. Both stabilized and isochronal deliverability testing of gas wells will be illustrated. Prerequisite: PEGN423. 3 hours lecture; 3 semester hours.

PEGN513. RESERVOIR SIMULATION I. 3.0 Semester Hrs.

The course provides the rudiments of reservoir simulation, which include flow equations, solution methods, and data requirement. Specifically, the course covers: equations of conservation of mass, conservation of momentum, and energy balance; numerical solution of flow in petroleum reservoirs by finite difference (FD) and control volume FD; permeability tensor and directional permeability; non-Darcy flow; convective flow and numerical dispersion; grid orientation problems; introduction to finite element and mixed finite-element methods; introduction to hybrid analytical/numerical solutions; introduction to multi-phase flow models; relative permeability, capillary pressure and wettability issues; linear equation solvers; streamline simulation; and multi-scale simulation concept. Prerequisite: PEGN424 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 credit hours. 3 hours of lecture per week.

PEGN514. PETROLEUM TESTING TECHNIQUES. 3.0 Semester Hrs.

Investigation of basic physical properties of petroleum reservoir rocks and fluids. Review of recommended practices for testing drilling fluids and oil well cements. Emphasis is placed on the accuracy and calibration of test equipment. Quality report writing is stressed. Prerequisite: Graduate status. 2 hours lecture, 1 hour lab; 3 semester hours. Required for students who do not have a BS in PE.

PEGN515. RESERVOIR ENGINEERING PRINCIPLES. 3.0 Semester Hrs.

Reservoir Engineering overview. Predicting hydrocarbon in place; volumetric method, deterministic and probabilistic approaches, material balance, water influx, graphical techniques. Fluid flow in porous media; continuity and diffusivity equations. Well performance; productivity index for vertical, perforated, fractured, restricted, slanted, and horizontal wells, inflow performance relationship under multiphase flow conditions. Combining material balance and well performance equations. Future reservoir performance prediction; Muskat, Tarner, Carter and Tracy methods. Fetkovich decline curves. Reservoir simulation; fundamentals and formulation, streamline simulation, integrated reservoir studies. 3 hours lecture, 3 semester hours.

PEGN516. PRODUCTION ENGINEERING PRINCIPLES. 3.0 Semester Hrs.
Production Engineering Overview. Course provides a broad introduction to the practice of production engineering. Covers petroleum system analysis, well stimulation (fracturing and acidizing), artificial lift (gas lift, sucker rod, ESP, and others), and surface facilities. 3 hours lecture, 3 semester hours.

PEGN517. DRILLING ENGINEERING PRINCIPLES. 3.0 Semester Hrs.
Drilling Engineering overview. Subjects to be covered include overall drilling organization, contracting, and reporting; basic drilling engineering principles and equipment; drilling fluids, hydraulics, and cuttings transport; drillstring design; drill bits; drilling optimization; fishing operations; well control; pore pressure and fracture gradients, casing points and design; cementing; directional drilling and horizontal drilling. 3 hours lecture, 3 semester hours.

PEGN519. ADVANCED FORMATION EVALUATION. 3.0 Semester Hrs.
A detailed review of wireline well logging and evaluation methods stressing the capability of the measurements to determine normal and special reservoir rock parameters related to reservoir and production problems. Computers for log processing of single and multiple wells. Utilization of well logs and geology in evaluating well performance before, during, and after production of hydrocarbons. The sensitivity of formation evaluation parameters in the volumetric determination of petroleum in reservoirs. Prerequisite: PEGN419. 3 hours lecture; 3 semester hours.

PEGN522. ADVANCED WELL STIMULATION. 3.0 Semester Hrs.
Basic applications of rock mechanics to petroleum engineering problems. Hydraulic fracturing; acid fracturing, fracturing simulators; fracturing diagnostics; sandstone acidizing; sand control, and well bore stability. Different theories of formation failure, measurement of mechanical properties. Review of recent advances and research areas. Prerequisite: PEGN426. 3 hours lecture; 3 semester hours.

PEGN523. ADVANCED ECONOMIC ANALYSIS OF OIL AND GAS PROJECTS. 3.0 Semester Hrs.
Determination of present value of oil properties. Determination of severance, ad valorem, windfall profit, and federal income taxes. Analysis of profitability indicators. Application of decision tree theory and Monte Carlo methods to oil and gas properties. Economic criteria for equipment selection. Prerequisite: PEGN422 or EBGN504 or ChEN504 or MNGN427 or ChEN421. 3 hours lecture; 3 semester hours.

PEGN524. PETROLEUM ECONOMICS AND MANAGEMENT. 3.0 Semester Hrs.
Business applications in the petroleum industry are the central focus. Topics covered are: fundamentals of accounting, oil and gas accounting, strategic planning, oil and gas taxation, oil field deals, negotiations, and the formation of secondary units. The concepts are covered by forming companies that prepare proforma financial statements, make deals, drill for oil and gas, keep accounting records, and negotiate the participation formula for a secondary unit. Prerequisite: PEGN422. 3 hours lecture; 3 semester hours.

PEGN530. ENVIRONMENTAL, ENERGY, AND NATURAL RESOURCES LAW. 3.0 Semester Hrs.
Equivalent with CEEN492,CEEN592,ESGN490,ESGN502,
(II) Covered topics: a survey of United States (US) environmental law including the National Environmental Protection Act (NEPA), Resource Conservation and Recovery Act (RCRA), Clean Air Act (CAA), Clean Water Act (CWA), Safe Drinking Water Act (SDWA), Comprehensive Environmental Response Compensation and Liability Act (CERCLA), Toxic Substances Control Act (TSCA), and Oil Pollution Act (OPA); and US law and regulation of public lands, endangered species, timber, water, minerals, coal, oil, natural gas, nuclear power, hydroelectric power, and alternative energy resources. 3 hours lecture; 3 semester hours.

PEGN541. APPLIED RESERVOIR SIMULATION. 3.0 Semester Hrs.
Concepts of reservoir simulation within the context of reservoir management will be discussed. Course participants will learn how to use available flow simulators to achieve reservoir management objectives. They will apply the concepts to an open-ended engineering design problem. Prerequisites: PEGN424. 3 hours lecture; 3 semester hours.

PEGN542. INTEGRATED RESERVOIR CHARACTERIZATION. 3.0 Semester Hrs.
The course introduces integrated reservoir characterization from a petroleum engineering perspective. Reservoir characterization helps quantify properties that influence flow characteristics. Students will learn to assess and integrate data sources into a comprehensive reservoir model. Prerequisites: PEGN424. 3 hours lecture; 3 semester hours.

PEGN550. MODERN RESERVOIR SIMULATORS. 3.0 Semester Hrs.
Students will learn to run reservoir simulation software using a variety of reservoir engineering examples. The course will focus on the capabilities and operational features of simulators. Students will learn to use pre- and post-processors, fluid property analysis software, black oil and gas reservoir models, and compositional models. 3 hours lecture; 3 semester hours.

PEGN577. WORKOVER DESIGN AND PRACTICE. 3.0 Semester Hrs.
Workover Engineering overview. Subjects to be covered include Workover Economics, Completion Types, Workover Design Considerations, Wellbore Cleanout (Fishing), Workover Well Control, Tubing and Workstring Design, SlicklineOperations, Coiled Tubing Operations, Packer Selection, Remedial Cementing Design and Execution, Completion Fluids, Gravel Packing, and Acidizing. 3 hours lecture, 3 semester hours.

PEGN590. RESERVOIR GEOMECHANICS. 3.0 Semester Hrs.

The course provides an introduction to fundamental rock mechanics concepts and aims to emphasize their role in exploration, drilling, completion and production engineering operations. Basic stress and strain concepts, pore pressure, fracture gradient and in situ stress magnitude and orientation determination and how these properties are obtained from the field measurements, mechanisms of deformation in rock, integrated wellbore stability analysis, depletion induced compaction and associated changes in rock properties and formation strength, hydraulic fracturing and fracture stability are among the topics to be covered in this rock course. Naturally fractured formation properties and how they impact the characteristics measured in the laboratory and in field are also included in the curriculum. Several industry speakers are invited as part of the lecture series to bring practical aspects of the fundamentals of geomechanics covered in the classroom. In addition, Petrel, FLAC3D and FRACMAN software practices with associated assignments are offered to integrate field data on problems including in situ stress magnitude and orientations, pore pressure and fracture gradient prediction and rock property determination using laboratory core measurements, logs, seismic, geological data. Problems are assign for students to use the field and laboratory data to obtain static and dynamic moduli, rock failure criteria, wellbore stress concentration and failure, production induced compaction/subsidence and hydraulic fracture mechanics.

PEGN591. SHALE RESERVOIR ENGINEERING. 3.0 Semester Hrs.

Equivalent with PEGN615,

Fundamentals of shale-reservoir engineering and special topics of production from shale reservoirs are covered. The question of what makes shale a producing reservoir is explored. An unconventional understanding of shale-reservoir characterization is emphasized and the pitfalls of conventional measurements and interpretations are discussed. Geological, geomechanical, and engineering aspects of shale reservoirs are explained. Well completions with emphasis on hydraulic fracturing and fractured horizontal wells are discussed from the viewpoint of reservoir engineering. Darcy flow, diffusive flow, and desorption in shale matrix are covered. Contributions of hydraulic and natural fractures are discussed and the stimulated reservoir volume concept is introduced. Interactions of flow between fractures and matrix are explained within the context of dual-porosity modeling. Applications of pressure-transient, rate-transient, decline-curve and transient-productivity analyses are covered. Field examples are studied. 3 hours lecture; 3 semester hours.

PEGN592. GEOMECHANICS FOR UNCONVENTIONAL RESOURCES. 3.0 Semester Hrs.

A wide spectrum of topics related to the challenges and solutions for the exploration, drilling, completion, production and hydraulic fracturing of unconventional resources including gas and oil shale, heavy oil sand and carbonate reservoirs, their seal formations is explored. The students acquire skills in integrating and visualizing multidiscipline data in Petrel (a short tutorial is offered) as well as assignments regarding case studies using field and core datasets. The role of integrating geomechanics data in execution of the exploration, drilling, completion, production, hydraulic fracturing and monitoring of pilots as well as commercial applications in unlocking the unconventional resources are pointed out using examples. Prerequisite: PEGN590. 3 hours lecture; 3 semester hours.

PEGN593. ADVANCED WELL INTEGRITY. 3.0 Semester Hrs.

Fundamentals of wellbore stability, sand production, how to keep wellbore intact is covered in this course. The stress alterations in near wellbore region and associated consequences in the form of well failures will be covered in detailed theoretically and with examples from deepwater conventional wells and onshore unconventionalwell operations. Assignments will be given to expose the students to the real field data to interpret and evaluate cases to determinepractical solutions to drilling and production related challenges. Fluid pressure and composition sensitivity of various formations will be studied. 3 hours lecture; 3 semester hours.

PEGN594. ADVANCED DIRECTIONAL DRILLING. 3.0 Semester Hrs.

Application of directional control and planning to drilling. Major topics covered include: Review of procedures for the drilling of directional wells. Section and horizontal view preparation. Two and three dimensional directional planning. Collision diagrams. Surveying and trajectory calculations. Surface and down hole equipment. Common rig operating procedures, and horizontal drilling techniques. Prerequisite: PEGN311 or equivalent. 3 hours lecture; 3 semester hours.

PEGN595. DRILLING OPERATIONS. 3.0 Semester Hrs.

Lectures, seminars, and technical problems with emphasis on well planning, rotary rig supervision, and field practices for execution of the plan. This course makes extensive use of the drilling rig simulator. Prerequisite: PEGN311. 3 hours lecture; 3 semester hours.

PEGN596. ADVANCED WELL CONTROL. 3.0 Semester Hrs.

Principles and procedures of pressure control are taught with the aid of a full-scale drilling simulator. Specifications and design of blowout control equipment for onshore and offshore drilling operations, gaining control of kicks, abnormal pressure detection, well planning for wells containing abnormal pressures, and kick circulation removal methods are taught. Students receive hands-on training with the simulator and its peripheral equipment. Prerequisite: PEGN311. 3 hours lecture; 3 semester hours.

PEGN597. TUBULAR DESIGN. 3.0 Semester Hrs.

Fundamentals of tubulars (casing, tubing, and drill pipe) design applied to drilling. Major topics covered include: Dogleg running loads. Directional hole considerations. Design criteria development. Effects of formation pressures. Stability loads after cementing. Effects of temperature, pressure, mud weights, and cement. Helical bending of tubing. Fishing loads. Micro-annulus problem. Strengths of API tubulars. Abrasive wear while rotating drill pipe. How to design for hydrogen sulfide and fatigue corrosion. Connection selection. Common rig operating procedures. Prerequisites: PEGN311 and PEGN361 or equivalent. 3 hours lecture; 3 semester hours.

PEGN598. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PEGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PEGN601. APPLIED MATHEMATICS OF FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.

This course is intended to expose petroleum-engineering students to the special mathematical techniques used to solve transient flow problems in porous media. Bessel?s equation and functions, Laplace and Fourier transformations, the method of sources and sinks, Green?s functions, and boundary integral techniques are covered. Numerical evaluation of various reservoir engineering solutions, numerical Laplace transformation and inverse transformation are also discussed. 3 hours lecture; 3 semester hours.

PEGN603. DRILLING MODELS. 3.0 Semester Hrs.

Analytical models of physical phenomena encountered in drilling. Casing and drilling failure from bending, fatigue, doglegs, temperature, stretch; mud filtration; corrosion; wellhead loads; and buoyancy of tubular goods. Bit weight and rotary speed optimization. Prerequisites: PEGN311 and PEGN361. 3 hours lecture; 3 semester hours.

PEGN604. INTEGRATED FLOW MODELING. 3.0 Semester Hrs.

Students will study the formulation, development and application of a reservoir flow simulator that includes traditional fluid flow equations and a petrophysical model. The course will discuss properties of porous media within the context of reservoir modeling, and present the mathematics needed to understand and apply the simulator. Simulator applications will be interspersed throughout the course. 3 hours lecture; 3 semester hours.

PEGN605. WELL TESTING AND EVALUATION. 3.0 Semester Hrs.

Various well testing procedures and interpretation techniques for individual wells or groups of wells. Application of these techniques to field development, analysis of well problems, secondary recovery, and reservoir studies. Productivity, gas well testing, pressure buildup and drawdown, well interference, fractured wells, type curve matching, and shortterm testing. Prerequisite: PEGN426. 3 hours lecture; 3 semester hours.

PEGN606. ADVANCED RESERVOIR ENGINEERING. 3.0 Semester Hrs.

A review of depletion type, gas-cap, and volatile oil reservoirs. Lectures and supervised studies on gravity segregation, moving gas-oil front, individual well performance analysis, history matching, performance prediction, and development planning. Prerequisite: PEGN423. 3 hours lecture; 3 semester hours.

PEGN607. PARTIAL WATER DRIVE RESERVOIRS. 3.0 Semester Hrs.

The hydrodynamic factors which influence underground water movement, particularly with respect to petroleum reservoirs. Evaluation of oil and gas reservoirs in major water containing formations. Prerequisite: PEGN424. 3 hours lecture; 3 semester hours.

PEGN608. MULTIPHASE FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.

The factors involved in multiphase fluid flow in porous and fractured media. Physical processes and mathematical models for micro- and macroscopic movement of multiphase fluids in reservoirs. Performance evaluation of various displacement processes in the laboratory as well as in the petroleum field during the secondary and EOR/IOR operations. Prerequisite: PEGN 424, 3 hours lecture; 3 semester hours.

PEGN614. RESERVOIR SIMULATION II. 3.0 Semester Hrs.

The course reviews the rudiments of reservoir simulation and flow equations, solution methods, and data requirement. The course emphasizes multi-phase flow and solution techniques; teaches the difference between conventional reservoir simulation, compositional modeling and multi-porosity modeling; teaches how to construct three-phase relative permeability from water-oil and gas-oil relative permeability data set; the importance of capillary pressure measurements and wetability issues; discusses the significance of gas diffusion and interphase mass transfer. Finally, the course develops solution techniques to include time tested implicit-pressure-explicitsaturation, sequential and fully implicit methods. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 credit hours. 3 hours of lecture per week.

PEGN619. GEOMECHANICALLY AND PHYSICOCHEMICALLY COUPLED FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.

The role of physic-chemisty and geomechanics on fluid flow in porous media will be included in addition to conventional fluid flow modeling and measurmeents in porous media. The conventional as well as unconventional reservoirs will be studied with the coupling of physicochemical effects and geomechanics stresses. Assignments will be given to expose the students to the real field data in interpretation and evaluation of filed cases to determine practical solutions to drilling and production related modeling challenges. 3 hours lecture; 3 semester hours.

PEGN620. NATURALLY FRACTURED RESERVOIRS -- ENGINEERING AND RESERVOIR SIMULATION. 3.0 Semester Hrs.

The course covers reservoir engineering, well testing, and simulation aspects of naturally fractured reservoirs. Specifics include: fracture description, connectivity and network; fracture properties; physical principles underlying reservoir engineering and modeling naturally fractured reservoirs; local and global effects of viscous, capillary, gravity and molecular diffusion flow; dual-porosity/dual-permeability models; multi-scale fracture model; dual-mesh model; streamlin model; transient testing with non-Darcy flow effects; tracer injection and breakthrough analysis; geomechanics and fractures; compositional model; coal-bed gas model; oil and gas from fractured shale; improved and enhanced oil recovery in naturally fracture reservoirs. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 hours lecture; 3 semester hours.

PEGN624. COMPOSITIONAL MODELING - APPLICATION TO ENHANCED OIL RECOVERY. 3.0 Semester Hrs.

Efficient production of rich and volatile oils as well as enhanced oil recovery by gas injection (lean and rich natural gas, CO2, N2, air, and steam) is of great interest in the light of greater demand for hydrocarbons and the need for CO2 sequestration. This course is intended to provide technical support for engineers dealing with such issues. The course begins with a review of the primary and secondary recovery methods, and will analyze the latest worldwide enhanced oil recovery production statistics. This will be followed by presenting a simple and practical solvent flooding model to introduce the student to data preparation and code writing. Next, fundamentals of phase behavior, ternary phase diagram, and the Peng-Robinson equation of state will be presented. Finally, a detailed set of flow and thermodynamic equations for a full-fledged compositional model, using molar balance, equation of motion and the afore-mentioned equation of state, will be developed and solution strategy will be presented. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 hours lecture; 3 semester hours.

PEGN660. CARBONATE RESERVOIRS - EXPLORATION TO PRODUCTION. 3.0 Semester Hrs.

Equivalent with GEOL660,

(II) This course will include keynote lectures and seminars on the reservoir characterization of carbonate rocks, including geologic description, petrophysics and production engineering. Course will focus on the integration of geology, rock physics, and engineering to improve reservoir performance. Application of reservoir concepts in hands-on exercises, that include a reflection seismic, well log, and core data. 3 hours lecture; 3 semester hours.

PEGN681. PETROLEUM ENGINEERING SEMINAR. 3.0 Semester Hrs.

Comprehensive reviews of current petroleum engineering literature, ethics, and selected topics as related to research and professionalism. 3 hours seminar; 3 semester hour.

PEGN698. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PEGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

College of Applied Science and Engineering

The College of Applied Science and Engineering (http://case.mines.edu) (CASE) comprises four academic departments:

- Department of Chemical and Biological Engineering
- Department of Chemistry
- Department of Metallurgical and Materials Engineering
- Department of Physics

Faculty in these departments also work with faculty in other colleges across the Mines campus to mentor graduate students in the these interdisciplinary graduate programs:

- Geochemistry
- Integrative Graduate Program in Quantitative Biosciences & E (https://QBE.mines.edu)ngineering
- Materials Science Program
- Nuclear Science and Engineering Program

Through these departments and programs CASE is proud to offer rigorous and highly-regarded educational programs, featuring an emphasis on problem solving and critical thinking, that address professional and societal needs. CASE departments and programs are also leaders in the creation of knowledge, recognizing the critical role research plays both in building a dynamic and rigorous intellectual learning community and in the advancement of humankind. The college structure facilitates collaboration among our departments, allowing our faculty and students to tackle the most challenging problems, with a particular emphasis on analysis of relevant systems at the molecular level.

The students and faculty in CASE are working collaboratively toward a shared vision of academic excellence. To learn more about each department’s extraordinary capabilities and accomplishments visit their websites and the College (https://case.mines.edu) website.

Chemical and Biological Engineering

Degrees Offered

- Master of Science (Chemical Engineering)
- Doctor of Philosophy (Chemical Engineering)

Program Description

The Chemical and Biological Engineering Department of the Colorado School of Mines is a dynamic, exciting environment for research and higher education. Mines provides a rigorous educational experience where faculty and top-notch students work together on meaningful research with far-reaching societal applications. Departmental research areas include bioengineering, catalysis, colloids and complex fluids, computational science, fuel cells, gas hydrates, membranes, polymers, and solar and electronic materials. Visit our website for additional information about our graduate program. http://chemeng.mines.edu/

Program Requirements

See required curriculum below.

Prerequisites

The program outlined here assumes that the candidate for an advanced degree has a background in chemistry, mathematics, and physics equivalent to that required for the BS degree in Chemical Engineering at the Colorado School of Mines. Undergraduate course deficiencies must be removed prior to enrollment in graduate coursework.

The essential undergraduate courses include:

CBEN201	MATERIAL AND ENERGY BALANCES	3.0
CBEN307	FLUID MECHANICS	3.0
CBEN308	HEAT TRANSFER	3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN375	CHEMICAL ENGINEERING SEPARATIONS	3.0
CBEN418	KINETICS AND REACTION ENGINEERING	3.0
Total Semester Hrs		18.0

Required Curriculum

Master of Science Program

Master of Science (with Thesis)

Students entering the Master of Science (with thesis) program with an acceptable undergraduate degree in chemical engineering are required to take a minimum of 18 semester hours of coursework. All students must complete:

Chemical Engineering core graduate courses		
CBEN507	APPLIED MATHEMATICS IN CHEMICAL ENGINEERING	3.0
CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	TRANSPORT PHENOMENA	3.0
CBEN518	REACTION KINETICS AND CATALYSIS	3.0
CBEN568	INTRODUCTION TO CHEMICAL ENGINEERING RESEARCH AND TEACHING	3.0
CBEN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	6.0
ELECT	Approved Coursework Electives	6.0
RESEARCH	Research Credits or Coursework	3.0
Total Semester Hrs		30.0

Students must take a minimum of 6 research credits, complete, and defend an acceptable Masters dissertation. Upon approval of the thesis committee, graduate credit may be earned for 400-level courses. Between coursework and research credits a student must earn a minimum of 30 total semester hours. Full-time Masters students must enroll in graduate colloquium (CBEN605) each semester.

Master of Science (non-thesis)

Students entering the Master of Science (non-thesis) program with an acceptable undergraduate degree in chemical engineering are required to take a minimum of 30 semester hours of coursework. All students must complete:

Chemical Engineering core graduate courses		
CBEN507	APPLIED MATHEMATICS IN CHEMICAL ENGINEERING	3.0
CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	TRANSPORT PHENOMENA	3.0
CBEN518	REACTION KINETICS AND CATALYSIS	3.0
ELECT	Approved Electives	18.0
Total Semester Hrs		30.0

Students may complete an acceptable engineering report for up to 6 hours of academic credit. Upon approval of the thesis committee, graduate credit may be earned for selected 400-level courses. Full-time Masters students must enroll in graduate colloquium (CBEN605) each semester.

CSM undergraduates enrolled in the combined BS/MS degree program must meet the requirements described above for the MS portion of their degree (both thesis and non-thesis). Students accepted into the combined program may take graduate coursework and/or research credits as an undergraduate and have them applied to their MS degree.

Doctor of Philosophy Program

The course of study for the PhD degree consists of a minimum of 30 semester hours of coursework. All PhD students must complete:

Core courses		
CBEN507	APPLIED MATHEMATICS IN CHEMICAL ENGINEERING	3.0
CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	TRANSPORT PHENOMENA	3.0
CBEN518	REACTION KINETICS AND CATALYSIS	3.0
CBEN568	INTRODUCTION TO CHEMICAL ENGINEERING RESEARCH AND TEACHING	3.0
CBEN6XX	600-Level Coursework Electives	6.0
CBEN707	Graduate Research Credit (up to 12 hours per semester)	42.0
ELECT	Approved Coursework Electives	9.0
Total Semester Hrs		72.0

In addition, students must complete and defend an acceptable Doctoral dissertation. Upon approval of the thesis committee, graduate credit may be earned for 400-level courses. Full-time PhD students must enroll in graduate colloquium (CBEN605) each semester.

Students in the PhD program are required to pass both a Qualifying Exam and the PhD Proposal Defense. After successful completion of 30 semester hours of coursework and completion of the PhD proposal defense, PhD candidates will be awarded a non-thesis Master of Science Degree. The additional requirements for the PhD program are described below.

PhD Qualifying Examination

The PhD qualifying examination will be offered twice each year, at the start and end of the Spring semester. All students who have entered the PhD program must take the qualifying examination at the first possible opportunity. However, a student must be in good academic standing (above 3.0 GPA) to take the qualifying exam. A student may retake the examination once if he/she fails the first time; however, the examination must be retaken at the next regularly scheduled examination time. Failure of the PhD qualifying examination does not disqualify a student for the MS degree, although failure may affect the student's financial aid status.

The qualifying examination will cover the traditional areas of Chemical Engineering, and will consist of two parts: GPA from core graduate classes (CBEN507, CBEN509, CBEN516, and CBEN518) and an oral examination. The oral examination will consist of a presentation by the student on a technical paper from chemical engineering literature. Students will choose a paper from a list determined by the faculty. Papers for the oral examination will be distributed well in advance of the oral portion of the exam so students have sufficient time to prepare their presentations. The student is required to relate the paper to the core chemical engineering classes and present a research plan, followed by questions from the faculty. A 1-2 page paper on the research plan is due the Friday prior to the oral examination.

If a student fails the first attempt at the qualifying exam, his/her grade from a 600 level Chemical Engineering elective can replace the lowest grade from the core graduate classes for, and only for, the GPA calculation defined above.

PhD Proposal Defense

After passing the Qualifying Exam, all PhD candidates are required to prepare a detailed written proposal on the subject of their PhD research topic. An oral examination consisting of a defense of the thesis proposal must be completed prior to their fifth semester. Written proposals must be submitted to the student's thesis committee no later than one week prior to the scheduled oral examination.

Two negative votes from the doctoral committee members are required for failure of the PhD Proposal Defense. In the case of failure, one re-examination will be allowed upon petition to the Department Head. Failure to complete the PhD Proposal Defense within the allotted time without an approved postponement will result in failure. Under extenuating circumstances a student may postpone the exam with approval of the Graduate Affairs committee, based on the recommendation of the student's thesis committee. In such cases, a student must submit a written request for postponement that describes the circumstances and proposes a new date. Requests for postponement must be presented to the thesis committee no later than 2 weeks before the end of the semester in which the exam would normally have been taken.

Dean of the College of Applied Sciences and Engineering

Michael J. Kaufman

Professors

Andrew M. Herring

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

David W.M. Marr

Colin A. Wolden

David T.W. Wu, by courtesy

Associate Professors

Sumit Agarwal

Moises A. Carreon

Keith B. Neeves

Amadeu K. Sum

Jennifer Wilcox

Ning Wu

Assistant Professors

Nanette Boyle

Kevin J. Cash

Diego A. Gómez-Gualdrón

Melissa D. Krebs

Joseph R. Samaniuk

Teaching Associate Professors

Jason C. Ganley, Assistant Department Head

Tracy Q. Gardner

Rachel M. Morrish

Cynthia L. Norrgran

Charles R. Vestal

Teaching Assistant Professors

Michael D.M. Barankin

C. Joshua Ramey

Professor of Practice

John L. Jechura

Professors Emeriti

Robert M. Baldwin

Annette L. Bunge

Anthony M. Dean

James F. Ely, University Professor Emeritus

John O. Golden

J. Thomas McKinnon

Ronald L. Miller

E. Dendy Sloan, Jr. , University Professor Emeritus

J. Douglas Way

Victor F. Yesavage

Courses

CBEN504. ADVANCED PROCESS ENGINEERING ECONOMICS. 3.0 Semester Hrs.
Equivalent with CHEN504,
Advanced engineering economic principles applied to original and alternate investments. Analysis of chemical and petroleum processes relative to marketing and return on investments. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN505. NUMERICAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.
Equivalent with CHEN505,
Engineering applications of numerical methods. Numerical integration, solution of algebraic equations, matrix 54 Colorado School of Mines Graduate Bulletin 2011 2012 algebra, ordinary differential equations, and special emphasis on partial differential equations. Emphasis on application of numerical methods to chemical engineering problems which cannot be solved by analytical methods. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN507. APPLIED MATHEMATICS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.
Equivalent with CHEN507,
(I, II) This course stresses the application of mathematics to problems drawn from chemical and biological engineering fundamentals such as thermodynamics, transport phenomena, and kinetics. Formulation and solution of ordinary and partial differential equations arising in chemical engineering or related processes or operations are discussed. Prerequisite: Undergraduate differential equations course; undergraduate chemical engineering courses covering reaction kinetics, and heat, mass and momentum transfer. 3 hours lecture; 3 semester hours.

CBEN509. ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.
Equivalent with CHEN509,
Extension and amplification of under graduate chemical engineering thermodynamics. Topics will include the laws of thermodynamics, thermodynamic properties of pure fluids and fluid mixtures, phase equilibria, and chemical reaction equilibria. Prerequisite: CBEN357 or equivalent. 3 hours lecture; 3 semester hours.

CBEN511. NEUROSCIENCE, MEMORY, AND LEARNING. 3.0 Semester Hrs.
Equivalent with CBEN411,
(II) This course relates the hard sciences of the brain and neuroscience to memory encoding and current learning theories. Successful students in the course should be able to read, understand, and critique current, scholarly literature on the topic of Neuroscience, Memory, and Learning. When this course is cross-listed and concurrent with CBEN411, students that enroll in CBEN511 will complete additional and/or more complex assignments. Pre-requisites: CBEN110, CBEN120, CHGN221, CHGN222, PHGN100, and PHGN200. 3 hours lecture, 3 semester hours.

CBEN513. SELECTED TOPICS IN CHEMICAL ENGINEERING. 1-3 Semester Hr.
Equivalent with CHEN513,
Selected topics chosen from special interests of instructor and students. Course may be repeated for credit on different topics. Prerequisite: none. 1 to 3 semester hours lecture/discussion; 1 to 3 semester hours.

CBEN516. TRANSPORT PHENOMENA. 3.0 Semester Hrs.
Equivalent with CHEN516,
(I) Principles of momentum, heat, and mass transport with applications to chemical and biological processes. Analytical methods for solving ordinary and partial differential equations in chemical engineering with an emphasis on scaling and approximation techniques. Convective transport in the context of boundary layer theory and development of heat and mass transfer coefficients. Introduction to computational methods for solving coupled transport problems in irregular geometries. 3 hours lecture; 3 semester hours.

CBEN518. REACTION KINETICS AND CATALYSIS. 3.0 Semester Hrs.
Equivalent with CHEN518,
(I) This course applies the fundamentals of kinetics, transport and thermodynamics to the analysis of gas-phase and catalytic reactions. A focus is placed on a molecular description of chemical kinetics with applications to the design and analysis chemical and biological reactors, complex reaction networks, and catalysis. Prerequisite: CBEN418 or equivalent. 3 hours lecture; 3 semester hours.

CBEN524. COMPUTER-AIDED PROCESS SIMULATION. 3.0 Semester Hrs.
Equivalent with CHEN524,
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. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN531. IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.
Equivalent with BELS531,
(II) 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. Prerequisites: Biology BIOL110 or equivalent or graduate standing.

CBEN535. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 3.0 Semester Hrs.
Equivalent with CHEN435,CHEN535,MLGN535,PHGN435,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. 1 hour lecture, 4 hours lab; 3 semester hours.

CBEN550. MEMBRANE SEPARATION TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CHEN550,
This course is an introduction to the fabrication, characterization, and application of synthetic membranes for gas and liquid separations. Industrial membrane processes such as reverse osmosis, filtration, pervaporation, and gas separations will be covered as well as new applications from the research literature. The course will include lecture, experimental, and computational (molecular simulation) laboratory components. Prerequisites: CBEN375, CBEN430. 3 hours lecture; 3 semester hours.

CBEN554. APPLIED BIOINFORMATICS. 3.0 Semester Hrs.
Equivalent with BELS554,
(II) 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. General Biology BIOL110 or Graduate standing.

CBEN555. POLYMER AND COMPLEX FLUIDS COLLOQUIUM. 1.0 Semester Hr.
Equivalent with BELS555,CHEN555,CHGN555,MLGN555,
The Polymer and Complex Fluids Group at the Colorado School of Mines combines expertise in the areas of flow and field based transport, intelligent design and synthesis as well as nanomaterials and nanotechnology. A wide range of research tools employed by the group includes characterization using rheology, scattering, microscopy, microfluidics and separations, synthesis of novel macromolecules as well as theory and simulation involving molecular dynamics and Monte Carlo approaches. The course will provide a mechanism for collaboration between faculty and students in this research area by providing presentations on topics including the expertise of the group and unpublished, ongoing campus research. Prerequisites: none. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

CBEN568. INTRODUCTION TO CHEMICAL ENGINEERING RESEARCH AND TEACHING. 3.0 Semester Hrs.
Equivalent with CHEN568,
(I) Students will be expected to apply chemical engineering principles to critically analyze theoretical and experimental research results in the chemical engineering literature, placing it in the context of the related literature, and interact effectively with students in classroom. Skills to be developed and discussed include oral presentations, technical writing, proposal writing, principles of hypothesis driven research, critical review of the literature, research ethics, research documentation (the laboratory notebook), research funding, types of research, pedagogical methods, and assessment tools. Prerequisites: graduate student in Chemical and Biological Engineering in good standing. 3 semester hours.

CBEN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CHEN569,EGGN569,MEGN569,MLGN569,MTGN569,
(I) 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 credit hours.

CBEN570. INTRODUCTION TO MICROFLUIDICS. 3.0 Semester Hrs.
Equivalent with CHEN570,
This course introduces the basic principles and applications of microfluidics 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. Students will critically analyze the literature in this emerging field. Prerequisites: CBEN307 or equivalent. 3 hours lecture, 3 semester hours.

CBEN580. NATURAL GAS HYDRATES. 3.0 Semester Hrs.
Equivalent with CHEN580,
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.

CBEN584. FUNDAMENTALS OF CATALYSIS. 3.0 Semester Hrs.
Equivalent with CHEN584,
The basic principles involved in the preparation, charac terization, testing and theory of heterogeneous and homo geneous catalysts are discussed. Topics include chemisorption, adsorption isotherms, diffusion, surface kinetics, promoters, poisons, catalyst theory and design, acid base catalysis and soluble transition metal complexes. Examples of important industrial applications are given. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CBEN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CBEN604. TOPICAL RESEARCH SEMINARS. 1.0 Semester Hr.
Equivalent with CHEN604,
Lectures, reports, and discussions on current research in chemical engineering, usually related to the student?s thesis topic. Sections are operated independently and are directed toward different research topics. Course may be repeated for credit. Prerequisite: none. 1 hour lecture-discussion; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

CBEN605. COLLOQUIUM. 1.0 Semester Hr.

Equivalent with CHEN605,

Students will attend a series of lectures by speakers from industry, academia, and government. Primary emphasis will be on current research in chemical engineering and related disciplines, with secondary emphasis on ethical, philosophical, and career-related issues of importance to the chemical engineering profession. Prerequisite: Graduate status. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 10 hours.

CBEN608. ADVANCED TOPICS IN FLUID MECHANICS. 1-3 Semester Hr.

Equivalent with CHEN608,

Indepth analysis of selected topics in fluid mechanics with special emphasis on chemical engineering applications. Prerequisite: CBEN508. 1 to 3 hours lecture discussion; 1 to 3 semester hours.

CBEN609. ADVANCED TOPICS IN THERMODYNAMICS. 1-3 Semester Hr.

Equivalent with CHEN609,

Advanced study of thermodynamic theory and application of thermodynamic principles. Possible topics include stability, critical phenomena, chemical thermodynamics, thermodynamics of polymer solutions and thermodynamics of aqueous and ionic solutions. Prerequisite: none. 1 to 3 semester hours.

CBEN610. APPLIED STATISTICAL THERMODYNAMICS. 3.0 Semester Hrs.

Equivalent with CHEN610,

Principles of relating behavior to microscopic properties. Topics include element of probability, ensemble theory, application to gases and solids, distribution theories of fluids, and transport properties. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN617. GRADUATE TRANSPORT PHENOMENA II. 3.0 Semester Hrs.

(II) Analysis of momentum, heat, and mass transfer problems using advanced analytical and numerical methods with an emphasis on coupled transport problems and irregular geometries. Advanced analytical techniques may include regular and singular perturbation analysis, eigenvalue problems, finite Fourier transforms, and Laplace transforms. Numerical methods for solving differential equations include finite differences, finite elements, Monte Carlo methods, and computational fluid dynamics. Prerequisite: CBEN516. 3 hours lecture; 3 semester hours.

CBEN620. ENGINEERING OF SOFT MATTER. 3.0 Semester Hrs.

(II) Soft matter is a field of inquiry involving physical systems having low moduli and which are structured on length scales ranging from about 10 nanometers up to 100 microns. This graduate level class provides a survey of relevant material systems including polymers, colloids, surfactants, liquid crystals, and biological materials. The course emphasis is on the chemical physics of soft materials and therefore requires a high level of mathematical sophistication; students should have the equivalent of one semester of graduate level applied mathematics as a prerequisite. A term paper in the form of a short publishable review of a relevant topic is a major component of the class. Prerequisites: the equivalent of one semester of graduate level applied mathematics. 3 hours lecture; 3 semester hours.

CBEN624. APPLIED STATISTICAL MECHANICS. 4.0 Semester Hrs.

(II) This course will introduce the both rigorous and approximate theories to estimate the macroscopic thermodynamic properties of systems based on laws that control the behavior of molecules. Course contents include classical dynamics and phase space, different types of ensembles, ideal and interacting gases, modern theory of liquids, ideal solids, as well as molecular simulation techniques. Prerequisite: undergraduate-level classical thermodynamics. 4 hours lecture; 4 semester hours.

CBEN625. MOLECULAR SIMULATION. 3.0 Semester Hrs.

Equivalent with CHEN625,

Principles and practice of modern computer simulation techniques used to understand solids, liquids, and gases. Review of the statistical foundation of thermodynamics followed by in-depth discussion of Monte Carlo and Molecular Dynamics techniques. Discussion of intermolecular potentials, extended ensembles, and mathematical algorithms used in molecular simulations. Prerequisites: CBEN509 or equivalent, CBEN610 or equivalent recommended. 3 hours lecture; 3 semester hours.

CBEN690. SUPERVISED TEACHING OF CHEMICAL ENGINEERING. 2.0 Semester Hrs.

Equivalent with CHEN690,

Individual participation in teaching activities. Discussion, problem review and development, guidance of laboratory experiments, course development, supervised practice teaching. Course may be repeated for credit. Prerequisite: Graduate standing, appointment as a graduate student instructor. 6 to 10 hours supervised teaching; 2 semester hours.

CBEN698. SPECIAL TOPICS IN CHEMICAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CBEN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CBEN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

Equivalent with CHEN707,

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Chemistry

Degrees Offered

- Master of Science (Chemistry; thesis and non-thesis options)
- Doctor of Philosophy (Applied Chemistry)

All graduate degree programs in the Department of Chemistry have been admitted to the Western Regional Graduate Program (WICHE). This program allows residents of Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming to register at Colorado resident tuition rates.

Program Description

The Department of Chemistry offers graduate degrees in Chemistry and Applied Chemistry. This section of the Catalog only describes the Chemistry and Applied Chemistry degrees. For Geochemistry degrees, please consult the Geochemistry section of the catalog.

Prerequisites

A candidate for an advanced degree in the Chemistry program should have completed an undergraduate program in Chemistry which is essentially equivalent to that offered by the Department of Chemistry at the Colorado School of Mines. Undergraduate deficiencies will be determined by faculty in the Department of Chemistry through interviews and/or placement examinations at the beginning of the student's first semester of graduate work.

Required Curriculum

Chemistry

A student in the chemistry program, in consultation with the advisor and thesis committee, selects the program of study. Initially, before a thesis advisor and thesis committee have been chosen, the student is advised by a temporary advisor and by the Graduate Affairs Committee in the Department of Chemistry & Geochemistry.

M.S. Degree (chemistry, thesis option): The program of study includes coursework, research, and the preparation and oral defense of an MS thesis based on the student's research. The required courses are:

CHGN502	ADVANCED INORGANIC CHEMISTRY	3.0
CHGN503	ADV PHYSICAL CHEMISTRY I	4.0
CHGN505	ADVANCED ORGANIC CHEMISTRY	3.0
CHGN507	ADVANCED ANALYTICAL CHEMISTRY	3.0
CHGN560	GRADUATE SEMINAR, M.S. (M.S.-level seminar)	1.0

Students should enroll in CHGN560 in the first semester of their degree program. A minimum of 36 semester hours, including at least 24 semester hours of course work, are required. At least 15 of the required 24 semester hours of course work must be taken in the Department of Chemistry & Geochemistry at CSM. The student's thesis committee makes decisions on transfer credit. Up to 9 semester hours of graduate courses may be transferred from other institutions, provided that those courses have not been used as credit toward a Bachelor's degree.

Research-Intensive MS Degree: CSM undergraduates who enter the graduate program through the combined BS/MS program may use this option (thesis-based MS) to acquire a research-intensive MS degree by minimizing the time spent on coursework. This option requires a minimum of 12 hours of coursework up to six hours of which may be double counted from the student's undergraduate studies at CSM (see below).

M.S. Degree (chemistry, non-thesis option): The non-thesis M.S. degree requires 30 semester hours of course credit:

Course work	24.0
Independent study	6.0
Total Semester Hrs	30.0

The program of study includes coursework, independent study on a topic determined by the student and the student's faculty advisor, and the preparation of an oral presentation of a report based on the student's independent study topic. The required courses are:

CHGN502	ADVANCED INORGANIC CHEMISTRY	3.0
CHGN503	ADV PHYSICAL CHEMISTRY I	4.0
CHGN505	ADVANCED ORGANIC CHEMISTRY	3.0
CHGN507	ADVANCED ANALYTICAL CHEMISTRY	3.0
CHGN560	GRADUATE SEMINAR, M.S. (M.S.-level seminar)	1.0
Total Semester Hrs		14.0

Students should enroll in CHGN560 in the first semester of their degree program. At least 21 of the required 30 semester hours of course work must be taken as a registered master's degree student at CSM. The student's committee makes decisions on courses to be taken, transfer credit, and examines the student's written report. Up to 15 semester hours of graduate courses may be transferred into the degree program, provided that those courses have not been used as credit toward a Bachelor's degree.

Ph.D. Degree (Applied Chemistry): The program of study for the Ph.D. degree in Applied Chemistry includes coursework, a comprehensive examination, a thesis proposal, research, and the preparation and oral defense of a Ph.D. thesis based on the student's research.

Coursework. The required courses are:

CHGN502	ADVANCED INORGANIC CHEMISTRY	3.0
CHGN503	ADV PHYSICAL CHEMISTRY I	4.0
CHGN505	ADVANCED ORGANIC CHEMISTRY	3.0
CHGN507	ADVANCED ANALYTICAL CHEMISTRY	3.0
CHGN560	GRADUATE SEMINAR, M.S. (M.S.-level seminar)	1.0
CHGN660	GRADUATE SEMINAR, Ph.D. (Ph.D.-level seminar)	1.0
Total Semester Hrs		15.0

The total hours of course work required for the Ph.D. degree is determined on an individual basis by the student's thesis committee. Up to 24 semester hours of graduate-level course work may be transferred from other institutions toward the Ph.D. degree provided that those courses have not been used by the student toward a Bachelor's degree. Up to 36 hours of credit may be transferred if the student has completed a Master's degree. The student's thesis committee may set additional course requirements and will make decisions on requests for transfer credit.

Seminar requirement. Students should enroll in CHGN560 in the first semester of their degree program. The CHGN560 seminar must be completed no later than the end of the student's second year of graduate studies at CSM. The semester after completion of the CHGN560 seminar, students must enroll in CHGN660. The CHGN660 seminar must include detailed research findings and interpretation of the student's Ph.D thesis research and must be presented close to, but before, the student's oral defense of the thesis.

Comprehensive examination. The comprehensive examination comprises a written literature review of the student's field of research, an oral presentation and defense of the literature review before the student's thesis committee, and oral answers to questions posed by the thesis committee during the defense. The literature review must be completed prior to the end of the student's second year of graduate studies. A student's thesis committee may, at its discretion, require additional components to the comprehensive examination process.

Thesis proposal. The thesis proposal should include a statement of the hypotheses, goals and objectives of the proposed research, the significance and novelty of the research in the context of previously published studies, a description of methodology and results to date, a timeline with milestones, and a description of how the student has contributed to the creation or direction of the project. The thesis proposal must be orally defended before the student's thesis committee prior to completion of the student's third year of studies.

Geochemistry

Please see the Geochemistry (http://catalog.mines.edu/graduate/programs/interdisciplinaryprograms/geochemistry) section of this bulletin for more information.

Fields of Research

Analytical and bioanalytical chemistry. Separation and characterization techniques for polymers, biopolymers, nano-particles and natural colloids. Biodetection of pathogens. Advanced separations for nuclear fuel cycle. Instrumental analysis.

Energy sciences. Alternative fuels. New materials and technologies for solar energy capture, conversion, and storage. Electrochemistry and Radiochemistry. Energy materials from chemical wastes.

Environmental chemistry. Detection and fate of anthropogenic contaminants in water, soil, and air. Acid mine drainage. Ecotoxicology. Environmental photochemistry. Cleaning of industrial pollutants.

Geochemistry and biogeochemistry. Microbial and chemical processes in global climate change, biomineralization, metal cycling, medical and archeological geochemistry, humic substances.

Inorganic Chemistry. Synthesis, characterization, and applications of metal, metal oxide, and semiconductor nanomaterials.

Nanoscale materials. Design, synthesis and characterization of new materials for catalysis, energy sciences, spectroscopic applications and drug delivery. Environmental fate of nanoparticles.

Organic Chemistry. Polymer design, synthesis and characterization. Catalysis. Alternative fuels.

Physical and Computational Chemistry. Computational chemistry for polymer design, clathrate hydrates, porous media, molecular simulation, energy sciences, biophysical chemistry, rational design of molecular materials, photochemical processes and excited state dynamics, and materials research. Surface-enhanced Raman spectroscopy. Laser Flash Photolysis.

Polymers. New techniques for controlling polymer architecture and composition. Theory and simulation. Separation and characterization.

CHGC503. INTRODUCTION TO GEOCHEMISTRY. 3.0 Semester Hrs.
(I) A comprehensive introduction to the basic concepts and principles of geochemistry, coupled with a thorough overview of the related principles of thermodynamics. Topics covered include: nucleosynthesis, origin of earth and solar system, chemical bonding, mineral chemistry, elemental distributions and geochemical cycles, chemical equilibrium and kinetics, isotope systematics, and organic and biogeochemistry. Prerequisite: Introductory chemistry, mineralogy and petrology. 3 hours lecture; 3 semester hours.

CHGC504. METHODS IN GEOCHEMISTRY. 2.0 Semester Hrs.
Sampling of natural earth materials including rocks, soils, sediments, and waters. Preparation of naturally heterogeneous materials, digestions, and partial chemical extractions. Principles of instrumental analysis including atomic spectroscopy, mass separations, and chromatography. Quality assurance and quality control. Interpretation and assessment of geochemical data using statistical methods. Prerequisite: Graduate standing in geochemistry or environmental science and engineering. 2 hours lecture; 2 semester hours.

CHGC505. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGN403,
(II) 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. Meets with CHGN403. CHGN403 and CHGC505 may not both be taken for credit. Prerequisites: GEGN101, CHGN122 and CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGC506. WATER ANALYSIS LABORATORY. 2.0 Semester Hrs.
Instrumental analysis of water samples using spectroscopy and chromatography. Methods for field collection of water samples and field measurements. The development of laboratory skills for the use of ICP-AES, HPLC, ion chromatography, and GC. Laboratory techniques focus on standard methods for the measurement of inorganic and organic constituents in water samples. Methods of data analysis are also presented. Prerequisite: Introductory chemistry, graduate standing. 3 hour laboratory, 1 hour lecture, 2 semester hours.

CHGC509. INTRODUCTION TO AQUEOUS GEOCHEMISTRY. 3.0 Semester Hrs.
Analytical, graphical and interpretive methods applied to aqueous systems. Thermodynamic properties of water and aqueous solutions. Calculations and graphical expression of acid-base, redox and solution-mineral equilibria. Effect of temperature and kinetics on natural aqueous systems. Adsorption and ion exchange equilibria between clays and oxide phases. Behavior of trace elements and complexation in aqueous systems. Application of organic geochemistry to natural aqueous systems. Light stable and unstable isotopic studies applied to aqueous systems. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours.

CHGC511. GEOCHEMISTRY OF IGNEOUS ROCKS. 3.0 Semester Hrs.
A survey of the geochemical characteristics of the various types of igneous rock suites. Application of major element, trace element, and isotope geochemistry to problems of their origin and modification. Prerequisite: Undergraduate mineralogy and petrology. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGC514. GEOCHEMISTRY THERMODYNAMICS AND KINETICS. 3.0 Semester Hrs.
(II) Fundamental principles of classical thermodynamics and kinetics with specific application to the earth sciences. Volume-temperature ? pressure relationships for solids, liquids, gases and solutions. Energy and the First Law, Entropy and the Second and Third Laws. Gibbs Free Energy, chemical equilibria and the equilibrium constant. Solutions and activity-composition relationships for solids, fluids and gases. Phase equilibria and the graphical representation of equilibira. Application of the fundamentals of kinetics to geochemical examples. Prerequisite: Introductory chemistry, introductory thermodynamics, mineralogy and petrology. 3 hours lecture, 3 semester hours. Offered in alternate years.

CHGC527. ORGANIC GEOCHEMISTRY OF FOSSIL FUELS AND ORE DEPOSITS. 3.0 Semester Hrs.
A study of organic carbonaceous materials in relation to the genesis and modification of fossil fuel and ore deposits. The biological origin of the organic matter will be discussed with emphasis on contributions of microorganisms to the nature of these deposits. Biochemical and thermal changes which convert the organic compounds into petroleum, oil shale, tar sand, coal and other carbonaceous matter will be studied. Principal analytical techniques used for the characterization of organic matter in the geosphere and for evaluation of oil and gas source potential will be discussed. Laboratory exercises will emphasize source rock evaluation, and oil-source rock and oil-oil correlation methods. Prerequisite: CHGN221, GEGN438. 2 hours lecture; 3 hours lab; 3 semester hours. Offered alternate years.

CHGC555. ENVIRONMENTAL ORGANIC CHEMISTRY. 3.0 Semester Hrs.
A study of the chemical and physical interactions which determine the fate, transport and interactions of organic chemicals in aquatic systems, with emphasis on chemical transformations of anthropogenic organic contaminants. Prerequisites: A course in organic chemistry and CHGN503, Advanced Physical Chemistry or its equivalent. Offered in alternate years. 3 hours lecture; 3 semester hours.

CHGC562. MICROBIOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs.
This course will cover the basic fundamentals of microbiology, such as structure and function of procaryotic versus eucaryotic cells; viruses; classification of micro-organisms; microbial metabolism, energetics, genetics, growth and diversity; microbial interactions with plants, animals, and other microbes. Additional topics covered will include various aspects of environmental microbiology such as global biogeochemical cycles, bioleaching, bioremediation, and wastewater treatment. Prerequisite: ESGN301. 3 hours lecture, 3 semester hours. Offered alternate years.

CHGC563. ENVIRONMENTAL MICROBIOLOGY. 2.0 Semester Hrs.
An introduction to the microorganisms of major geochemical importance, as well as those of primary importance in water pollution and waste treatment. Microbes and sedimentation, microbial leaching of metals from ores, acid mine water pollution, and the microbial ecology of marine and freshwater habitats are covered. Prerequisite: none. 1 hour lecture, 3 hours lab; 2 semester hours. Offered alternate years.

CHGC564. BIOGEOCHEMISTRY AND GEOMICROBIOLOGY. 3.0 Semester Hrs.
Designed to give the student an understanding of the role of living things, particularly microorganisms, in the shaping of the earth. Among the subjects will be the aspects of living processes, chemical composition and characteristics of biological material, origin of life, role of microorganisms in weathering of rocks and the early diagenesis of sediments, and the origin of petroleum, oil shale, and coal. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGC598. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGC599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGC698. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGC699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

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.
(I, II) 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.
(I, II, S) 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. Prerequisite: Grade of C- or better in CHGN121. 3 hours lecture; 3 hours lab, 4 semester hours.

CHGN125. MOLECULAR ENGINEERING & MATERIALS CHEMISTRY. 4.0 Semester Hrs.

(I,II) 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.

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.

Equivalent with DCGN209,

(I, II, S) 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.

CHGN221. ORGANIC CHEMISTRY I. 3.0 Semester Hrs.

(I,S) 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.

CHGN222. ORGANIC CHEMISTRY II. 3.0 Semester Hrs.

(II, S) Continuation of CHGN221. Prerequisites: Grade of C- or better in CHGN221. 3 hours lecture; 3 semester hours.

CHGN223. ORGANIC CHEMISTRY I LABORATORY. 1.0 Semester Hr.

(I,II, S) 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. Prerequisites: CHGN221 or concurrent enrollment. 3 hours laboratory, 1 semester hour.

CHGN224. ORGANIC CHEMISTRY II LABORATORY. 1.0 Semester Hr.

(II, S) Laboratory exercises using more advanced synthesis techniques. Experiments are designed to support concepts presented in CHGN222. Prerequisites: CHGN221, CHGN223, and CHGN222 or concurrent enrollment. 3 hours laboratory, 1 semester hour.

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.

(II) 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. Prerequisites: CHGN121 and CHGN122 or CHGN125. 3 hours lecture; 3 semester hours.

CHGN323. QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY. 2.0 Semester Hrs.

(II) Identification, separation and purification of organic compounds including use of modern physical and instrumental methods. Prerequisite: Grade of C- or better in CHGN222, CHGN224. 1 hour lecture; 3 hours lab; 2 semester hours.

CHGN335. INSTRUMENTAL ANALYSIS. 3.0 Semester Hrs.

(II) Principles of AAS, AES, Visible-UV, IR, NMR, XRF, XRD, XPS, electron, and mass spectroscopy; gas and liquid chromatography; data interpretation. Prerequisite: Grade of C- or better in CHGN122. 3 hours lecture; 3 semester hours.

CHGN336. ANALYTICAL CHEMISTRY. 3.0 Semester Hrs.

(I) Theory and techniques of gravimetry, titrimetry (acid-base, complexometric, redox, precipitation), electrochemical analysis, chemical separations; statistical evaluation of data. Prerequisite: Grade of C- or better in both CHGN122 and CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGN337. ANALYTICAL CHEMISTRY LABORATORY. 1.0 Semester Hr.

(I) (WI) Laboratory exercises emphasizing sample preparation and instrumental methods of analysis. Prerequisite: CHGN336 or concurrent enrollment. 3 hours lab; 1 semester hour.

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.

(I) 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. Prerequisite: CHGN222 and CHGN209. 3 hours lecture; 3 semester hours.

CHGN351. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I. 4.0 Semester Hrs.
(I,II,S) 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. Prerequisite: MATH225; PHGN200; Grade of C- or better in CHGN 122 or CHGN 125; and Grade of C- or better in CHGN209 or CBEN210. 3 hours lecture; 3 hours lab; 4 semester hours.

CHGN353. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II. 4.0 Semester Hrs.
(II) A continuation of CHGN351. Includes statistical thermodynamics, chemical kinetics, chemical reaction mechanisms, electrochemistry, and selected additional topics. Prerequisite: CHGN351. 3 hours lecture; 3 hours laboratory; 4 semester hours.

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.
(II) 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.

CHGN403. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGC505,
(II) Processes by which natural and anthro?pogenic 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 envi?ronments such as waste treatment facilities and the upper atmosphere. Prerequisites: CHGN222, CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGN406. INTRODUCTION TO GEOCHEMISTRY. 3.0 Semester Hrs.
(II) A comprehensive introduction to the basic concepts and principles of geochemistry, coupled with a thorough overview of the related principles of thermodynamics. Topics covered include: nucleosynthesis, origin of earth and solar system, chemical bonding, mineral chemistry, elemental distributions and geochemical cycles, chemical equilibrium and kinetics, isotope systematics, and organic and biogeochemistry. Prerequisites: CHGN121, CHGN122, and GEGN101. 4 hours lecture; 4 semester hours.

CHGN410. SURFACE CHEMISTRY. 3.0 Semester Hrs.
Equivalent with MLGN510,
(II) 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. 3 hours lecture; 3 semester hours.

CHGN411. APPLIED RADIOCHEMISTRY. 3.0 Semester Hrs.
(II) 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: CHGN121 and CHGN122. 3 hours lecture, 3 semester hours.

CHGN422. POLYMER CHEMISTRY LABORATORY. 1.0 Semester Hr.
(I) Prerequisites: CHGN221, CHGN223. 3 hours lab; 1 semester hour.

CHGN428. BIOCHEMISTRY. 3.0 Semester Hrs.
(I) 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. Prerequisite: CHGN222. 3 hours lecture; 3 semester hours.

CHGN429. BIOCHEMISTRY II. 3.0 Semester Hrs.
(I) 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. Prerequisites: CHGN428. 3 hours lecture; 3 semester hours.

CHGN430. INTRODUCTION TO POLYMER SCIENCE. 3.0 Semester Hrs.
Equivalent with CHEN415,MLGN530,
(I) 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.

CHGN462. MICROBIOLOGY. 3.0 Semester Hrs.
Equivalent with CHGN562,ESGN580,
(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.
(II) 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.
(S) (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. Prerequisites: CHGN323, CHGN341, and CHGN353. 6-week summer session; 6 semester hours.

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.

CHGN502. ADVANCED INORGANIC CHEMISTRY. 3.0 Semester Hrs.
(II) Detailed examination of topics such as ligand field theory, reaction mechanisms, chemical bonding, and structure of inorganic compounds. Emphasis is placed on the correlations of the chemical reactions of the elements with periodic trends and reactivities. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN503. ADV PHYSICAL CHEMISTRY I. 4.0 Semester Hrs.
(II) Quantum chemistry of classical systems. Principles of chemical thermodynamics. Statistical mechanics with statistical calculation of thermodynamic properties. Theories of chemical kinetics. Prerequisite: none. 4 hours lecture; 4 semester hours.

CHGN505. ADVANCED ORGANIC CHEMISTRY. 3.0 Semester Hrs.
Detailed discussion of the more important mechanisms of organic reaction. Structural effects and reactivity. The application of reaction mechanisms to synthesis and structure proof. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN507. ADVANCED ANALYTICAL CHEMISTRY. 3.0 Semester Hrs.
(I) Review of fundamentals of analytical chemistry. Literature of analytical chemistry and statistical treatment of data. Manipulation of real substances; sampling, storage, decomposition or dissolution, and analysis. Detailed treatment of chemical equilibrium as related to precipitation, acid-base, complexation and redox titrations. Potentiometry and UV-visible absorption spectrophotometry. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN508. ANALYTICAL SPECTROSCOPY. 3.0 Semester Hrs.
(II) Detailed study of classical and modern spectroscopic methods; emphasis on instrumentation and application to analytical chemistry problems. Topics include: UV-visible spectroscopy, infrared spectroscopy, fluorescence and phosphorescence, Raman spectroscopy, arc and spark emission spectroscopy, flame methods, nephelometry and turbidimetry, reflectance methods, Fourier transform methods in spectroscopy, photoacoustic spectroscopy, rapid-scanning spectroscopy. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN510. CHEMICAL SEPARATIONS. 3.0 Semester Hrs.
(II) Survey of separation methods, thermodynamics of phase equilibria, thermodynamics of liquid-liquid partitioning, various types of chromatography, ion exchange, electrophoresis, zone refining, use of inclusion compounds for separation, application of separation technology for determining physical constants, e.g., stability constants of complexes. Prerequisite: CHGN507. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN511. APPLIED RADIOCHEMISTRY. 3.0 Semester Hrs.
(II) The Applied Radiochemistry 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. Prerequisites: CHGN121/CHGN122. 3 hours lecture and discussion; 3 semester hours.

CHGN515. CHEMICAL BONDING IN MATERIALS. 3.0 Semester Hrs.
(I) Introduction to chemical bonding theories and calculations and their applications to solids of interest to materials science. The relationship between a material?s properties and the bonding of its atoms will be examined for a variety of materials. Includes an introduction to organic polymers. Computer programs will be used for calculating bonding parameters. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN523. SOLID STATE CHEMISTRY. 3.0 Semester Hrs.
(I) 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: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN536. ADVANCED POLYMER SYNTHESIS. 3.0 Semester Hrs.
(II) An advanced course in the synthesis of macromolecules. Various methods of polymerization will be discussed with an emphasis on the specifics concerning the syntheses of different classes of organic and inorganic polymers. Prerequisite: CHGN430, ChEN415, MLGN530. 3 hours lecture, 3 semester hours.

CHGN538. ORGANIC SEMICONDUCTORS: NEW TECHNOLOGIES FOR EMERGING APPLICATIONS. 3.0 Semester Hrs.

(II) Organic Light Emitting Diodes (OLEDs) is a display technology that can be found in many commercial products such as the smartphones and tablets. This technology was on the R&D bench-top just 10 years ago and has now reached high volume manufacturing. Other related technologies like organic photovoltaics (OPV) and organic thin film transistors (OTFT) are now on the heels of commercialization as well. This course will provide an overview on how this meteoric rise from bench-top to commercial products occurred as well as the design, synthesis and uses of conjugated organic small molecules, oligomers and polymers in applications such as OLEDs (for flat panel displays and lighting), OPV, OTFT, and sensors. Additional topics to be covered are factors governing the materials physical properties and structure-property relationship in electronic device applications. The prospect of using low cost printing techniques such as inkjet, screen, and gravure printing in the fabrication of roll-to-roll organic based devices will be discussed. Encapsulation, lifetime and reliability issues will also be presented. Prerequisites: Organic Chemistry 1 & 2 are encouraged. 3 hours lecture; 3 semester hours.

CHGN540. PROFESSION SKILLS FOR CHEMICAL SCIENTISTS. 1.0 Semester Hr.

(I) The goal of this course is to provide students a set of skills that are complementary to their core education. The contents of this course cover a broad range of topics that will provide the participants a perspective on careers in science and the skill sets necessary to be successful in each. These skills are in line with the latest recommendations of the American Chemical Society (ACS) and CSM educational goals. In particular, the 2013 ACS Presidential Commission Report on Graduate Education in the Chemical Sciences presents a platform for educational reform that includes a focus on multi-level (from general public to specialists) and multi-platform communication (formal and informal, written, oral), an understanding of the global chemical enterprise and the career possibilities within each, an understanding of networking and collaboration, etc. 1 hour lecture; 1 semester hour.

CHGN555. POLYMER AND COMPLEX FLUIDS COLLOQUIUM. 1.0 Semester Hr.

Equivalent with BELS555,CBEN555,CHEN555,MLGN555,
The Polymer and Complex Fluids Group at the Colorado School of Mines combines expertise in the areas of flow and field based transport, intelligent design and synthesis as well as nanomaterials and nanotechnology. A wide range of research tools employed by the group includes characterization using rheology, scattering, microscopy, microfluidics and separations, synthesis of novel macromolecules as well as theory and simulation involving molecular dynamics and Monte Carlo approaches. The course will provide a mechanism for collaboration between faculty and students in this research area by providing presentations on topics including the expertise of the group and unpublished, ongoing campus research. Prerequisites: none. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

CHGN560. GRADUATE SEMINAR, M.S.. 1.0 Semester Hr.

(I, II) Required for all candidates for the M.S. and Ph.D. degrees in chemistry and geochemistry. M.S. students must register for the course during each semester of residency. Ph.D. students must register each semester until a grade is received satisfying the prerequisites for CHGN660. Presentation of a graded non-thesis seminar and attendance at all departmental seminars are required. Prerequisite: Graduate student status. 1 semester hour.

CHGN580. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.

(II) Application of X-ray diffraction techniques for crystal and molecular structure determination of minerals, inorganic and organometallic compounds. Topics include the heavy atom method, data collection by moving film techniques and by diffractometers, Fourier methods, interpretation of Patterson maps, refinement methods, direct methods. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN581. ELECTROCHEMISTRY. 3.0 Semester Hrs.

(I) Introduction to theory and practice of electrochemistry. Electrode potentials, reversible and irreversible cells, activity concept. Interionic attraction theory, proton transfer theory of acids and bases, mechanisms and fates of electrode reactions. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN583. PRINCIPLES AND APPLICATIONS OF SURFACE ANALYSIS TECHNIQUES. 3.0 Semester Hrs.

(II) Instru mental techniques for the characterization of surfaces of solid materials; Applications of such techniques to polymers, corrosion, metallurgy, adhesion science, microelectronics. Methods of analysis discussed: x-ray photoelectron spectroscopy (XPS), auger electron spectroscopy (AES), ion scattering spectroscopy (ISS), secondary ion mass spectrometry (SIMS), Rutherford backscattering (RBS), scanning and transmission electron microscopy (SEM, TEM), energy and wavelength dispersive x-ray analysis; principles of these methods, quantification, instrumentation, sample preparation. Prerequisite: B.S. in Metallurgy, Chemistry, Chemical Engineering, Physics. 3 hours lecture; 3 semester hours.

CHGN584. FUNDAMENTALS OF CATALYSIS. 3.0 Semester Hrs.

(II) The basic principles involved in the preparation, characterization, testing and theory of heterogeneous and homo geneous catalysts are discussed. Topics include chemisorption, adsorption isotherms, diffusion, surface kinetics, promoters, poisons, catalyst theory and design, acid base catalysis and soluble transition metal complexes. Examples of important industrial applications are given. Prerequisite: CHGN222. 3 hours lecture; 3 semester hours.

CHGN585. CHEMICAL KINETICS. 3.0 Semester Hrs.

(II) Study of kinetic phenomena in chemical systems. Attention devoted to various theoretical approaches. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN598. SPECIAL TOPICS IN CHEMISTRY. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGN625. MOLECULAR SIMULATION. 3.0 Semester Hrs.
Principles and practice of modern computer simulation techniques used to understand solids, liquids, and gases. Review of the statistical foundation of thermodynamics followed by indepth discussion of Monte Carlo and Molecular Dynamics techniques. Discussion of intermolecular potentials, extended ensembles, and mathematical algorithms used in molecular simulations. Prerequisites: ChEN509 or equivalent, ChEN610 or equivalent recommended. 3 hours lecture; 3 semester hours.

CHGN660. GRADUATE SEMINAR, Ph.D.. 1.0 Semester Hr.
(I, II) Required of all candidates for the doctoral degree in chemistry or geochemistry. Students must register for this course each semester after completing CHGN560. Presentation of a graded nonthesis seminar and attendance at all department seminars are required. Prerequisite: CHGN560 or equivalent. 1 semester hour.

CHGN698. SPECIAL TOPICS IN CHEMISTRY. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Professors

Mark E. Eberhart

Thomas Gennett, Department Head

Mark P. Jensen, Grandey University Chair in Nuclear Science & Engineering

Daniel M. Knauss

Matthew C. Posewitz

James F. Ranville

Ryan M. Richards

Bettina M. Voelker

Kim R. Williams

David T. Wu

Associate Professors

Stephen G. Boyes

Alan S. Sellinger

Assistant Professors

Dylan Domaille

Svitlana Pylypenko

Jenifer C. Shafer

Brian G. Trewyn

Shubham Vyas

Teaching Professors

Renee L. Falconer, Assistant Department Head

Mark R. Seger

Teaching Associate Professors

Allison G. Caster

Edward A. Dempsey

Angela Sower

Research Assistant Professors

Fiona Davies

Yuan Yang

Research Faculty

Jesse Hensley

Bryan Pivovar

Dan Ruddy

Robert Rundberg

Affiliated Faculty

Joseph Meyer, Principle Scientist

Derek Vardon, Research Engineer

Professor Emeriti

Scott W. Cowley

Stephen R. Daniel

Dean W. Dickerhoof

Kenneth W. Edwards

Ronald W. Klusman

Donald Langmuir

Donald L. Macalady

Patrick MacCarthy

Michael J. Pavelich

E. Craig Simmons

Kent J. Voorhees

Thomas R. Wildeman

Robert D. Witters

Metallurgical and Materials Engineering

Degrees Offered

- Master of Engineering (Metallurgical and Materials Engineering)
- Master of Science (Metallurgical and Materials Engineering)
- Doctor of Philosophy (Metallurgical and Materials Engineering)

Program Description

The program of study for the Master or Doctor of Philosophy degrees in Metallurgical and Materials Engineering is selected by the student in consultation with her or his advisor, and with the approval of the Thesis Committee. The program can be tailored within the framework of the regulations of the Graduate School to match the student's interests while maintaining the main theme of materials engineering and processing. There are three areas of specialization within the Department:

- Physical and Mechanical Metallurgy;
- Physicochemical Processing of Materials; and,
- Ceramic Engineering.

The Department is home to six research centers:

- Advanced Coatings and Surface Engineering Laboratory (ACSEL);
- Advanced Steel Processing and Products Research Center (ASPPRC);
- Center for Advanced Non Ferrous Structural Alloys (CANFSA)
- Center for Welding Joining, and Coatings Research (CWJCR);
- Colorado Center for Advanced Ceramics (CCAC); and,
- Kroll Institute for Extractive Metallurgy (KIEM).

The Nuclear Science and Engineering Center (NuSEC) also operates closely with the Department.

A Graduate Certificate is offered by each Department Center – the requirements for the Graduate Certificate are:

1. Be admitted to MME Graduate Certificate Program upon the recommendation of the MME Department.
2. Complete a total of 12 hours of course credits of which only 3 credit hours can be at the 400 level.

The specific courses to be taken are determined by the Graduate Advisor in the Department Center selected by the candidate. A cumulative grade point average of B or better must be maintained while completing these requirements.

Degree Program Requirements

The program requirements for the three graduate degrees offered by the Department are listed below:

Master of Engineering Degree

Requirements: A minimum total of 30.0 credit hours consisting of:

1. A minimum of 24.0 credit hours of approved course work and 3.0 hours of either a three credit hour research based Independent Study (MTGN599) or a designated design course (minimum of 3 credit hours) and graduate seminar enrollment during duration of program (up to a maximum of 1 credit hour).
2. The designated design courses include the following courses: MTGN414, MTGN445, MTGN450, MTGN461, MTGN464, MTGN466, MTGN475/477, MTGN549, MTGN564, MTGN560. Alternative courses can be substituted with approval from the advisor and department head.

Restrictions:

1. Only three (3) credit hours of independent course work, e.g. MTGN599, may be applied toward the degree.
2. A maximum of nine (9) credit hours of approved 400-level course work may be applied toward the degree.
3. Courses taken to remove deficiencies may not be applied toward the degree.

The Master of Engineering Degree can also be obtained as part of the combined undergraduate/graduate degree program. See the Physics section of the undergraduate bulletin for more details.

Master of Science Degree

Requirements: A minimum total of 30.0 credit hours, consisting of:

1. A minimum of 18.0 credit hours of approved course work and a minimum of 6.0 hours of graduate research-credits listed under MTGN707.
2. Approval of all courses by the Thesis Committee and the Department Head. (Thesis Committee: consisting of 3 or more members, including the advisor and at least 1 additional member from the Metallurgical and Materials Engineering Department.)
3. Submittal and successful oral defense of a thesis before a Thesis Committee. The thesis must present the results of original scientific research or development.

Restrictions:

1. Only three (3) credit hours of independent course work, e.g. MTGN599, may be applied toward the degree.
2. A maximum of nine (9) credit hours of approved 400-level course work may be applied toward the degree.
3. Courses taken to remove deficiencies may not be applied toward the degree.

Doctor of Philosophy Degree

Requirements: A minimum total of 72.0 credit hours consisting of:

1. A minimum of 36.0 credit hours of approved course work and a minimum of 24.0 hours of research-credits (MTGN707). Credit hours previously earned for a Master's degree may be applied, subject to approval, toward the Doctoral degree provided that the Master's degree was in Metallurgical and Materials Engineering or a similar field. At least 21.0 credit hours of approved course work must be taken at the Colorado School of Mines.
2. All courses and any applicable Master's degree credit-hours must be approved by the Thesis Committee and the Department Head (Thesis Committee consisting of: 5 or more members, including the advisor, at least 2 additional members from the Metallurgical and Materials Engineering Department, and at least 1 member from outside the Department.)
3. Presentation of a Proposal on the Thesis-Research Project to the Thesis Committee.

4. Passing grade on the written and oral Qualifying-Process (Q.P.) Examinations.
5. Presentation of a Progress Report on their Research Project to the Thesis Committee; this presentation is usually 6 months after successfully completing the Q.P. Examinations and no fewer than 6 weeks before the Defense of Thesis.
6. Submittal and successful oral-defense of a thesis before the Thesis Committee. The thesis must present the results of original scientific research or development.

Restrictions:

1. Only six (6) credit hours of independent course work, e.g. MTGN599, may be applied toward the degree.
2. A maximum of nine (9) credit hours of approved 400-level course work may be applied toward the degree.
3. Courses taken to remove deficiencies may not be applied toward the degree.

Prerequisites

The entering graduate-student in the Department of Metallurgical and Materials Engineering must have completed an undergraduate program equivalent to that required for the B.S. degree in: Metallurgical and Materials Engineering, Materials Science or a related field. This undergraduate program should have included a background in science fundamentals and engineering principles. A student, who possesses this background but has not taken specific undergraduate courses in Metallurgical and Materials Engineering, will be allowed to rectify these course deficiencies at the beginning of their program of study.

Fields of Research

Ceramic Research

- Ceramic processing
- Ceramic-metal composites
- Functional materials
- Ion implantation
- Modeling of ceramic processing
- Solid oxide fuel cell materials and membranes
- Transparent conducting oxides

Coatings Research

- Chemical vapor deposition
- Coating materials, films and applications
- Epitaxial growth
- Interfacial science
- Physical vapor deposition
- Surface mechanics
- Surface physics
- Tribology of thin films and coatings

Extractive and Mineral Processing Research

- Chemical and physical processing of materials
- Electrometallurgy
- Hydrometallurgy
- Mineral processing
- Pyrometallurgy
- Recycling and recovery of materials
- Thermal plasma processing

Nonferrous Research

- Aluminum alloys
- High entropy alloys
- Magnesium alloys
- Nonferrous structural alloys
- Shape memory alloys
- Superalloys
- Titanium alloys

Polymers and Biomaterials Research

- Advanced polymer membranes and thin films
- Biopolymers
- Bio-mimetic and bio-inspired materials engineering
- Calcium phosphate based ceramics
- Drug delivery
- Failure of medical devices
- Interfaces between materials and tissue
- Living/controlled polymerization
- Organic-inorganic hybrid materials
- Porous structured materials
- Self- and directed-assembly
- Structural medical alloys
- Tissue as a composite material

Steel Research

- Advanced high strength steels
- Advanced steel coatings
- Carburized steels
- Deformation behavior of steels
- Fatigue behavior of steels
- Microalloyed steels
- Nickel-based steels
- Quench and partitioned steels
- Plate steels
- Sheet steels

Welding and Joining Research

- Brazing of ultra wide gaps
- Explosive processing of materials
- Laser welding and processing
- Levitation for kinetics and surface tension evaluation
- Materials joining processes
- Pyrochemical kinetics studies using levitation
- Underwater and under oil welding
- Welding and joining science
- Welding rod development
- Welding stress management
- Weld metallurgy
- Weld wire development

Nuclear Materials Research

- Nuclear materials characterization
- Nuclear materials processing
- Nuclear materials properties

Experimental Methods

- 3D atom probe tomography
- Atomic force microscopy
- Computer modeling and simulation
- Electron microscopy
- Mathematical modeling of material processes
- Nanoindentation
- Non-destructive evaluation
- X-ray diffraction

Other Research Areas

- Combustion synthesis
- Corrosion science and engineering
- Failure analysis
- Mechanical metallurgy
- Phase transformation and mechanism of microstructural change
- Physical metallurgy
- Reactive metals properties
- Strengthening mechanisms
- Structure-property relationships

MTGN505	CRYSTALLOGRAPHY AND DIFFRACTION	3.0
MTGN511	SPECIAL METALLURGICAL AND MATERIALS ENGINEERING PROBLEMS	1-3
MTGN512	SPECIAL METALLURGICAL AND MATERIALS ENGINEERING PROBLEMS	1-3
MTGN514	DEFECT CHEMISTRY AND TRANSPORT PROCESSES IN CERAMIC SYSTEMS	3.0
MTGN516	MICROSTRUCTURE OF CERAMIC SYSTEMS	3.0
MTGN517	REFRACTORIES	3.0
MTGN518	PHASE EQUILIBRIA IN CERAMIC SYSTEMS	3.0
MTGN523	APPLIED SURFACE AND SOLUTION CHEMISTRY	3.0
MTGN526	GEL SCIENCE AND TECHNOLOGY	3.0
MTGN527	SOLID WASTE MINIMIZATION AND RECYCLING	3.0
MTGN528	EXTRACTIVE METALLURGY OF COPPER, GOLD AND SILVER	3.0
MTGN529	METALLURGICAL ENVIRONMENT	3.0
MTGN530	ADVANCED IRON AND STEELMAKING	3.0
MTGN531	THERMODYNAMICS OF METALLURGICAL AND MATERIALS PROCESSING	3.0
MTGN532	PARTICULATE MATERIAL PROCESSING I - COMMINUTION AND PHYSICAL SEPARATIONS	3.0
MTGN533	PARTICULATE MATERIAL PROCESSING II - APPLIED SEPARATIONS	3.0
MTGN534	CASE STUDIES IN PROCESS DEVELOPMENT	3.0
MTGN535	PYROMETALLURGICAL PROCESSES	3.0
MTGN536	OPTIMIZATION AND CONTROL OF METALLURGICAL SYSTEMS	3.0
MTGN537	ELECTROMETALLURGY	3.0
MTGN538	HYDROMETALLURGY	3.0
MTGN539	PRINCIPLES OF MATERIALS PROCESSING REACTOR DESIGN	3.0
MTGN541	INTRODUCTORY PHYSICS OF METALS	3.0
MTGN542	ALLOYING THEORY, STRUCTURE, AND PHASE STABILITY	3.0
MTGN543	THEORY OF DISLOCATIONS	3.0
MTGN544	FORGING AND DEFORMATION MODELING	3.0
MTGN545	FATIGUE AND FRACTURE	3.0
MTGN546	CREEP AND HIGH TEMPERATURE MATERIALS	3.0
MTGN547	PHASE EQUILIBRIA IN MATERIALS SYSTEMS	3.0
MTGN548	TRANSFORMATIONS IN METALS	3.0
MTGN549	CURRENT DEVELOPMENTS IN FERROUS ALLOYS	3.0
MTGN551	ADVANCED CORROSION ENGINEERING	3.0
MTGN552	INORGANIC MATRIX COMPOSITES	3.0
MTGN553	STRENGTHENING MECHANISMS	3.0
MTGN554	OXIDATION OF METALS	3.0
MTGN555	SOLID STATE THERMODYNAMICS	3.0
MTGN556	TRANSPORT IN SOLIDS	3.0
MTGN557	SOLIDIFICATION	3.0
MTGN560	ANALYSIS OF METALLURGICAL FAILURES	3.0
MTGN561	PHYSICAL METALLURGY OF ALLOYS FOR AEROSPACE	3.0
MTGN564	ADVANCED FORGING AND FORMING	3.0
MTGN565	MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES	3.0
MTGN569	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MTGN570	BIOCOMPATIBILITY OF MATERIALS	3.0
MTGN571	METALLURGICAL AND MATERIALS ENGINEERING LABORATORY	1-3
MTGN572	BIOMATERIALS	3.0
MTGN580	ADVANCED WELDING METALLURGY	3.0
MTGN581	WELDING HEAT SOURCES AND INTERACTIVE CONTROLS	3.0
MTGN582	MECHANICAL PROPERTIES OF WELDED JOINTS	3.0
MTGN583	PRINCIPLES OF NON-DESTRUCTIVE TESTING AND EVALUATION	3.0
MTGN584	NON-FUSION JOINING PROCESSES	3.0
MTGN586	DESIGN OF WELDED STRUCTURES AND ASSEMBLIES	3.0
MTGN587	PHYSICAL PHENOMENA OF WELDING AND JOINING PROCESSES	3.0
MTGN591	PHYSICAL PHENOMENA OF COATING PROCESSES	3.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
MTGN605	ADVANCED TRANSMISSION ELECTRON MICROSCOPY	2.0
MTGN605L	ADVANCED TRANSMISSION ELECTRON MICROSCOPY LABORATORY	1.0
MTGN631	TRANSPORT PHENOMENA IN METALLURGICAL AND MATERIALS SYSTEMS	3.0

MTGN671	ADVANCED MATERIALS LABORATORY	1-3
MTGN672	ADVANCED MATERIALS LABORATORY	1-3
MTGN696	VAPOR DEPOSITION PROCESSES	3.0
MTGN697	MICROSTRUCTURAL EVOLUTION OF COATINGS AND THIN FILMS	3.0
MTGN700	GRADUATE RESEARCH CREDIT: MASTER OF ENGINEERING	1-6
MTGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	1-15

Professors

Angus Rockett, Department Head

Corby G. Anderson, Harrison Western Professor

Michael J. Kaufman, Dean of CASE

Stephen Liu, American Bureau of Shipping Endowed Chair Professor of Metallurgical and Materials Engineering

Ryan O'Hayre, Program Director of Material Science

Ivar E. Reimanis, Professor, Herman F. Coors Distinguished Professor of Ceramics

Sridhar Seetharaman

John G. Speer, John Henry Moore Distinguished Professor of Metallurgical and Materials Engineering

Patrick R. Taylor, George S. Ansell Distinguished Professor of Chemical Metallurgy

Associate Professors

Amy Clarke

Kip O. Findley

Brian Gorman

Jeffrey C. King

Corinne E. Packard

Steven W. Thompson

Assistant Professors

Geoff L. Brennecka

Kester Clarke, FIERF Professor

Emmanuel De Moor

Vladan Stevanovic

Zhenzhen Yu

Teaching Professor

Gerald Bourne, Assistant Department Head

Research Professors

Richard K. Ahrenkiel

William (Grover) Coors

Ivan Cornejo

Robert Field

Terry Lowe

Stephen Midson

Paul Queneau

D. (Erik) Spiller

James C. Williams

Research Associate Professors

Robert Cryderman

Carole Graas

Juan Carlos Madeni

Brock O'Kelly

Edgar Vidal

Gary Zito

Research Assistant Professors

David Diercks

Judith C. Gomez

Michael Sanders

Professors Emeriti

Glen R. Edwards, University Professor Emeritus

John P. Hager, University Professor Emeritus

George Krauss, University Professor Emeritus

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, University Professor Emeritus

Chester J. Van Tyne, Professor Emeritus

Associate Professors Emeriti

Gerald L. DePoorter

Robert H. Frost

Physics

Degrees Offered

- Master of Science (Physics)
- Doctor of Philosophy (Applied Physics)

Program Description

The Physics Department at Mines offers a full program of instruction and research leading to the M.S. in Physics or Ph.D. in Applied Physics and is part of interdisciplinary programs in Materials Science and in Nuclear Engineering, through which students can obtain both the M.S. and the Ph.D degrees. The research in these graduate programs is supported by external grants and contracts totaling $5.18M/year. Research in the Department is organized under three primary themes: subatomic physics, condensed matter physics, and applied optics. With 23 faculty, 52 graduate students, and 239 undergraduate physics majors, the Physics Department at Mines is a vibrant intellectual community providing high-quality education in state-of-the-art facilities.

Graduate students are given a solid background in the fundamentals of classical and modern physics at an advanced level and are encouraged early in their studies to learn about the research interests of the faculty so that a thesis topic can be identified.

Program Requirements

Students entering graduate programs in the Physics Department will select an initial program in consultation with the departmental graduate student advising committee until such time as a research field has been chosen and a thesis committee appointed.

Master of Science

Requirements: 20 semester hours of course work in an approved program, plus 16 semester hours of research credit, with a satisfactory thesis.

Doctor of Philosophy

Requirements: 32 semester hours of course work in an approved program, plus 40 semester hours of research credit, with a satisfactory thesis. 12 semester hours of course work will be in a specialty topic area defined in consultation with the thesis advisor. Possible specialty topic areas within the Physics Department exist in Optical Science and Engineering, Condensed Matter Physics, Theoretical Physics, Renewable Energy Physics, and Nuclear/Particle Physics and Astrophysics.

To demonstrate adequate preparation for the Ph.D. degree in Applied Physics, each student must achieve a grade of 3.0 or better in each core course. Students not meeting this standard must pass oral examinations covering the relevant core courses or retake the courses with a grade of 3.0 or better within one year. This process is part of the requirement for admission to candidacy, which full time Ph.D. students must complete within two calendar years of admission, as described in the campus-wide graduate degree requirements (http://bulletin.mines.edu/graduate/programs) section of this bulletin. Other degree requirements, time limits, and procedural details can be found in the Physics Department Graduate Student Advising Brochure.

Physics Colloquium

All full-time physics graduate students must attend the Physics Colloquium, which is represented in the curriculum by the Graduate Seminar courses. Students must take one of these courses every semester that they are enrolled at CSM. Those students who are in the M.S. Program, sign up for PHGN501 (fall) and PHGN502 (spring). Students in the Ph.D. program sign up for PHGN601 (fall) and PHGN602 (spring). At the end of each semester students are assigned either a satisfactory or unsatisfactory progress grade, based on attendance, until the final semester of the student's degree program, when a letter grade is assigned based on all prior semesters' attendance grades. As a result, while these courses are taken each year, only 1 hour total of course credit is conferred for each of 501, 502, 601, or 602. Students who have official part-time status and who have already taken at least one semester of 501 and 502 for the M.S. degree, or 601 and 602 for the Ph.D. degree are not required to sign up for Graduate Seminar during subsequent semesters.

Prerequisites

The Graduate School of the Colorado School of Mines is open to graduates from four-year programs at accredited colleges or universities. Admission to the Physics Department M.S. and Ph.D. programs is competitive and is based on an evaluation of undergraduate performance, standardized test scores, and references. The undergraduate course of study of each applicant is evaluated according to the requirements of the Physics Department.

Required Curriculum

Master of Science in Physics

Core Courses		
PHGN511	MATHEMATICAL PHYSICS	3.0
PHGN520	QUANTUM MECHANICS I	3.0
	Select one of the following:	3.0
PHGN505	CLASSICAL MECHANICS I	
PHGN507	ELECTROMAGNETIC THEORY I	
PHGN521	QUANTUM MECHANICS II	
PHGN530	STATISTICAL MECHANICS	
PH ELECT	Electives	9.0
PHGN501 & PHGN502	GRADUATE SEMINAR and GRADUATE SEMINAR *	2.0
PHGN707	Master's Thesis	16.0
Total Semester Hrs		36.0

* Graduate Seminar: Each full-time M.S. graduate student will register for Graduate Seminar each semester for a total of 2 semester hours of credit cumulative over the degree.

Doctor of Philosophy in Applied Physics

Core Courses		
PHGN505	CLASSICAL MECHANICS I	3.0
PHGN507	ELECTROMAGNETIC THEORY I	3.0
PHGN511	MATHEMATICAL PHYSICS	3.0
PHGN520	QUANTUM MECHANICS I	3.0
PHGN521	QUANTUM MECHANICS II	3.0
PHGN530	STATISTICAL MECHANICS	3.0

PHGN601 & PHGN602	ADVANCED GRADUATE SEMINAR and ADVANCED GRADUATE SEMINAR *	2.0
PH ELECT	Special topic area electives	12.0
PHGN707	Doctoral Thesis	40.0
Total Semester Hrs		72.0

* Graduate Seminar: Each full-time Ph.D. graduate student will register for Graduate Seminar each semester for a total of 2 semester hours of cumulative credit over the degree.

Fields of Research

Applied Optics: lasers, ultrafast optics and x-ray generation, spectroscopy, near-field and multiphoton microscopy, non-linear optics, quasi-optics and millimeter waves.

Ultrasonics: laser ultrasonics, resonant ultrasound spectroscopy, wave propagation in random media.

Subatomic: low energy nuclear physics, nuclear astrophysics, cosmic ray physics, nuclear theory, fusion plasma diagnostics.

Materials Physics: photovoltaics, nanostructures and quantum dots, thin film semiconductors, transparent conductors, amorphous materials, thermoelectric materials, plasmonics, first principles materials theory.

Condensed Matter: x-ray diffraction, Raman spectroscopy, self assembled systems, soft condensed matter, condensed matter theory, quantum chaos, quantum information and quantum many body theory.

Surface and Interfaces: x-ray photoelectron spectroscopy, Auger spectroscopy, scanning probe microscopies, second harmonic generation.

Professors

Lincoln D. Carr

Reuben T. Collins

Charles G. Durfee III

Uwe Greife, Department Head

Mark T. Lusk

Frederic Sarazin

Jeff A. Squier

Lawrence R. Wiencke

Associate Professors

Eliot Kapit

Timothy R. Ohno

Eric S. Toberer

Assistant Professors

Zhexuan Gong

Kyle G. Leach

Susanta K. Sarkar

Meenakshi Singh

Jeramy D. Zimmerman

Teaching Professors

Kristine E. Callan

Alex T. Flournoy

Patrick B. Kohl

H. Vincent Kuo

Todd G. Ruskell

Charles A. Stone

Teaching Assistant Professor

Bethany R. Wilcox

Research Professor

Mark W. Coffey

Research Associate Professor

Wendy Adams Spencer

Research Assistant Professors

P. David Flammer

Laith Haddad

Lakshmi Krishna

Nitin Kumar

Gavriil Shchedrin

K. Xerxes Steirer

Professors Emeriti

F. Edward Cecil

Thomas E. Furtak

Frank V. Kowalski

P. Craig Taylor

John Trefny, President Emeritus

Don L. Williamson

Associate Professors Emeriti

David M. Wood

Courses

PHGN501. GRADUATE SEMINAR. 1.0 Semester Hr.
(I) M.S. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN502. GRADUATE SEMINAR. 1.0 Semester Hr.
(II) M.S. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN503. RESPONSIBLE CONDUCT OF RESEARCH. 1.0 Semester Hr.
(II) This course introduces students to the various components of responsible research practices. Subjects covered move from issues related to professional rights and obligations through those related to collaboration, communication and the management of grants, to issues dealing with intellectual property. The course culminates with students writing an ethics essay based on a series of topics proposed by the course instructor. 1 hour lecture; 1 semester hour.

PHGN504. RADIATION DETECTION AND MEASUREMENT. 3.0 Semester Hrs.
Physical principles and methodology of the instrumentation used in the detection and measurement of ionizing radiation. Prerequisite: none. 3 hours lecture; 3 semester hours.

PHGN505. CLASSICAL MECHANICS I. 3.0 Semester Hrs.
(I) Review of Lagrangian and Hamiltonian formulations in the dynamics of particles and rigid bodies; kinetic theory; coupled oscillations and continuum mechanics; fluid mechanics. Prerequisite: PHGN350 or equivalent. 3 hours lecture; 3 semester hours.

PHGN507. ELECTROMAGNETIC THEORY I. 3.0 Semester Hrs.
(II) To provide a strong background in electromagnetic theory. Electrostatics, magnetostatics, dynamical Maxwell equations, wave phenomena. Prerequisite: PHGN462 or equivalent and PHGN511. 3 hours lecture; 3 semester hours.

PHGN511. MATHEMATICAL PHYSICS. 3.0 Semester Hrs.
(I) Review of complex variable and finite and infinite-dimensional linear vector spaces. Sturm-Liouville problem, integral equations, computer algebra. Prerequisite: PHGN311 or equivalent. 3 hours lecture; 3 semester hours.

PHGN520. QUANTUM MECHANICS I. 3.0 Semester Hrs.
(II) Schroedinger equation, uncertainty, change of representation, one-dimensonal problems, axioms for state vectors and operators, matrix mechanics, uncertainty relations, time-independent perturbation theory, time-dependent perturbations, harmonic oscillator, angular momentum; semiclassical methods, variational methods, two-level system, sudden and adiabatic changes, applications. Prerequisite: PHGN511 and PHGN320 or equivalent. 3 hours lecture; 3 semester hours.

PHGN521. QUANTUM MECHANICS II. 3.0 Semester Hrs.
(I) Review of angular momentum, central potentials and applications. Spin; rotations in quantum mechanics. Formal scattering theory, Born series, partial wave analysis. Addition of angular momenta, Wigner-Eckart theorem, selection rules, identical particles. Prerequisite: PHGN520. 3 hours lecture; 3 semester hours.

PHGN530. STATISTICAL MECHANICS. 3.0 Semester Hrs.
(I) Review of thermodynamics; equilibrium and stability; statistical operator and ensemblesl ideal systems; phase transitions; non-equilibrium systems. Prerequisite: PHGN341 or equivalent and PHGN520. Co-requisite: PHGN521. 3 hours lecture; 3 semester hours.

PHGN535. INTERDISCIPLINARY SILICON PROCESSING LABORATORY. 3.0 Semester Hrs.
Equivalent with CBEN435,CBEN535,CHEN435,CHEN535,MLGN535,PHGN435,
(II) Explores the application of science and engineering principles to the fabrication and testing of microelectronic devices with emphasis on specific unit operations and interrelation among processing steps. Teams work together to fabricate, test, and optimize simple devices. Prerequisite: none. 1 hour lecture, 4 hours lab; 3 semester hours.

PHGN542. SOLID STATE DEVICES AND PHOTOVOLTAIC APPLICATIONS. 3.0 Semester Hrs.
(II) An overview of the physical principles involved in the characterization, and operation of solid state devices. Topics will include: semiconductor physics, electronic transport, recombination and generation, intrinsic and extrinsic semiconductors, electrical contacts, p-n junction devices (e.g., LEDs, solar cells, lasers, particle detectors); other semiconductor devices (e.g., bipolar junction transistors and field effect transistors and capacitors). There will be emphasis on optical interactions and application to photovoltaic devices. Prerequisite: PHGN440 or equivalent. 3 hours lecture; 3 semester hours.

PHGN550. NANOSCALE PHYSICS AND TECHNOLOGY. 3.0 Semester Hrs.
An introduction to the basic physics concepts involved in nanoscale phenomena, processing methods resulting in engineered nanostructures, and the design and operation of novel structures and devices which take advantage of nanoscale effects. Students will become familiar with interdisciplinary aspects of nanotechnology, as well as with current nanoscience developments described in the literature. Prerequisites: PHGN320, PHGN341, co-requisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN566. 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 optimazation, diffraction, linear systems and optical transfer functions, detectors, and optical system examples. Prerequisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN570. FOURIER AND PHYSICAL OPTICS. 3.0 Semester Hrs.
This course addresses the propagation of light through optical systems. Diffraction theory is developed to show how 2D Fourier transforms and linear systems theory can be applied to imaging systems. Analytic and numerical Fourier and microscopes, spectrometers and holographic imaging. They are also applied to temporal propagation in ultrafast optics. Prerequisite: PHGN462 or equivalent. 3 hours lecture; 3 semester hours.

PHGN585. NONLINEAR OPTICS. 3.0 Semester Hrs.
An exploration of the nonlinear response of a medium (semiclassical and quantum descriptions) and nonlinear wave mixing and propagation. Analytic and numeric techniques to treat nonlinear dynamics are developed. Applications to devices and modern research areas are discussed, including harmonic and parametric wave modulation, phase conjugation, electro-optic modulation. Prerequiste: PHGN462 or equivalent, PHGN520. 3 hours lecture; 3 semester hours.

PHGN590. NUCLEAR REACTOR PHYSICS. 3.0 Semester Hrs.
Bridges the gap between courses in fundamental nuclear physics and the practice of electrical power production using nuclear reactors. Review of nuclear constituents, forces, structure, energetics, decay and reactions; interaction of radiation with matter, detection of radiation; nuclear cross sections, neutron induced reactions including scattering, absorption, and fission; neutron diffusion, multiplication, criticality; simple reactor geometries and compositions; nuclear reactor kinetics and control; modeling and simulation of reactors. Prerequisite: PHGN422.

PHGN598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PHGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PHGN601. ADVANCED GRADUATE SEMINAR. 1.0 Semester Hr.
(I) Ph.D. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN602. ADVANCED GRADUATE SEMINAR. 1.0 Semester Hr.
(II) Ph.D. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN608. ELECTROMAGNETIC THEORY II. 3.0 Semester Hrs.
Spherical, cylindrical, and guided waves; relativistic 4-dimensional formulation of electromagnetic theory. Prerequisite: PHGN507. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN612. MATHEMATICAL PHYSICS II. 3.0 Semester Hrs.
Continuation of PHGN511. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN623. NUCLEAR STRUCTURE AND REACTIONS. 3.0 Semester Hrs.
The fundamental physics principles and quantum mechanical models and methods underlying nuclear structure, transitions, and scattering reactions. Prerequisite: PHGN521. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN624. NUCLEAR ASTROPHYSICS. 3.0 Semester Hrs.
The physical principles and research methods used to understand nucleosynthesis and energy generation in the universe. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN641. ADVANCED CONDENSED MATTER PHYSICS. 3.0 Semester Hrs.
Provides working graduate-level knowledge of applications of solid state physics and important models to crystalline and non-crystalline systems in two and three dimensions. Review of transport by Bloch electrons; computation, interpretation of band structures. Interacting electron gas and overview of density functional theory. Quantum theory of optical properties of condensed systems; Kramers-Kronig analysis, sum rules, spectroscopies. Response and correlation functions. Theoretical models for metal-insulator and localization transitions in 1, 2, 3 dimensions (e.g., Mott, Hubbard, Anderson, Peierls distortion). Boltzmann equation. Introduction to magnetism; spin waves. Phenomenology of soft condensed matter: order parameters, free energies. Conventional superconductivity. Prerequisites: PHGN440 or equivalent, PHGN520, PHGN530. 3 hours lecture; 3 semester hours.

PHGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PHGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PHGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Interdisciplinary Programs

Please choose from the list of links on the left to access more information.

Advanced Manufacturing

DEGREES OFFERED

- Certificate in Advanced Manufacturing
- Master of Science in Advanced Manufacturing (Non-Thesis)

PROGRAM DESCRIPTION

The interdisciplinary Advanced Manufacturing graduate program will prepare graduates to meet the challenges of careers in advanced manufacturing.

Program Requirements

Program Requirements

Professional Graduate Certificate (12 credit hours)

AMGN401/501	Introduction to Additive Manufacturing (pre-or-co-requiste for the other three core courses	3.0
AMGN598	Structural Materials for Additive Manufacturing	3.0
AMGN598	Data-Driven Materials Manufacturing	3.0
AMGN498/598	Design for Additive Manufacturing	3.0
Total Semester Hrs		12.0

Master of Science, Non-Thesis (30 credit hours)

AMGN401/501	Introduction to Additive Manufacturing (pre-or-co-requiste for the other three core courses	3.0
AMGN598	Structural Materials for Additive Manufacturing	3.0
AMGN598	Data-Driven Materials Manufacturing	3.0
AMGN498/598	Design for Additive Manufacturing	3.0
AMGNXXX	Advanced Manufacturing Electives Up to 6 hours may be replaced with project-based indepent study	18.0
Total Semester Hrs		30.0

The Advanced Manufacturing program will be anchored by four signature core courses (three of which will be new to the catalog) and will offer a diverse array of electives drawn from an approved list of existing courses within the ME, MME, EE, CS, Physics and Math departments. Students who choose the MS-NT degree option will choose their electives with the intent of specializing in one of two key areas (or they can choose to diversify across both areas):

- Additive Manufacturing of Structural Materials
- Data-Driven Materials Manufacturing

Advanced Manufacturing Electives:

Additive Manufacturing of Structural Materials		
MEGN511	FATIGUE AND FRACTURE	3.0
MEGN515	COMPUTATIONAL MECHANICS	3.0
MLGN505	MECHANICAL PROPERTIES OF MATERIALS	3.0
MTGN514	DEFECT CHEMISTRY AND TRANSPORT PROCESSES IN CERAMIC SYSTEMS	3.0
MTGN557	SOLIDIFICATION	3.0
MTGN560	ANALYSIS OF METALLURGICAL FAILURES	3.0
MTGN564	ADVANCED FORGING AND FORMING	3.0
MTGN565	MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES	3.0
MTGN580	ADVANCED WELDING METALLURGY	3.0
PHGN585	NONLINEAR OPTICS	3.0
Data-Driven Materials Manufacturing		
CSCI507	INTRODUCTION TO COMPUTER VISION	3.0
CSCI508	ADVANCED TOPICS IN PERCEPTION AND COMPUTER VISION	3.0
CSCI575	MACHINE LEARNING	3.0
EENG509	SPARSE SIGNAL PROCESSING	3.0
EENG511	CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS	3.0
EENG515	MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS	3.0
EENG517	THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS	3.0
MATH530	STATISTICAL METHODS I	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
MEGN544	ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL	3.0
MEGN545	ADVANCED ROBOT CONTROL	3.0
MEGN587	NONLINEAR OPTIMIZATION	3.0
MEGN588	INTEGER OPTIMIZATION	3.0
MEGN688	ADVANCED INTEGER OPTIMIZATION	3.0

Data Center Engineering

DEGREES OFFERED

- Certificate in Data Center Engineering

PROGRAM DESCRIPTION

The post-baccalaureate certificate program in Data Center Engineering is an online program targeted to train recent graduates or mid-career professionals with a B.S. in engineering, computer science, or applied and engineering physics who are interested in careers and/or opportunities in data center engineering and management.

Program Requirements

DTCN501	INTRODUCTION TO DATA CENTER ENGINEERING	3.0
DTCN502	DATA CENTER INFRASTRUCTURE MANAGEMENT	3.0
DTCN503	DATA CENTER ENGINEERING GRADUATE SEMINAR	1.0
DTCN591	DATA CENTER ENGINEERING DESIGN AND ANALYSIS	2.0
ELECT XXX	TECHNICAL ELECTIVE Topics such as, planetary science, remote sensing, mineral economics, materials extraction, and electrochemical systems engineering.	3.0
Total Semester Hrs		12.0

Technical Electives:

CEEN501	LIFE CYCLE ASSESSMENT	3.0
CSCI471	COMPUTER NETWORKS I	3.0
CSCI565	DISTRIBUTED COMPUTING SYSTEMS	3.0
EENG581	POWER SYSTEM OPERATION AND MANAGEMENT	3.0
EENG586	COMMUNICATION NETWORKS FOR POWER SYSTEMS	3.0
MEGN485	MANUFACTURING OPTIMIZATION WITH NETWORK MODELS	3.0
MEGN567	HVAC AND BUILDING ENERGY SYSTEMS	3.0

DTCN501. INTRODUCTION TO DATA CENTER ENGINEERING. 3.0 Semester Hrs.
(I, II) This unique course will develop students' foundational knowledge in critical disciplines related to large-scale data center infrastructure design and performance. The course is intended for students with a B.S. in engineering, computer science, or applied and engineering physics who are interested in careers and/or opportunities in data center engineering and management. The course will incorporate real data center examples for introducing analysis of data center design and computing hardware and network requirements; engineering principles for data center power system design, distribution, and control; heat transfer systems for computer system thermal management and building HVAC; and large-scale data file organization, information system architecture, and network and software security. The course will conclude with lectures and an assignment related to sustainability and robustness for data center engineering and design. 3 hours lecture; 3 semester hours.

DTCN502. DATA CENTER INFRASTRUCTURE MANAGEMENT. 3.0 Semester Hrs.
(I, II) This course conveys the basic principles for operating, managing, and optimizing the hardware and software necessary for a large, modern data center. Students will learn how data center components are integrated and managed through software for various applications and in general for security, efficiency, adaptability, robustness, and sustainability. It is intended for graduate students with backgrounds in engineering or computer science. The students will become familiar with best practices in the industry and will demonstrate their knowledge by developing a operations management plan for a specific data center application. 3 hours lecture; 3 semester hours.

DTCN503. DATA CENTER ENGINEERING GRADUATE SEMINAR. 1.0 Semester Hr.
(I, II) The Data Center Engineering Seminar will provide students a broad knowledge of current industry and research developments in analysis, design, and operations of Data Center Engineering through once a week discussions and/or seminars from invited guest speakers presenting topics related to data center design, operations, and economics. Students will prepare several short reports on industry developments and/or academic research related to presentations and will deliver a technical presentation and lead a subsequent discussion on an approved topic relevant for the industry. Corequisite: DTCN501. 1 hour seminar; 1 semester hour.

DTCN591. DATA CENTER ENGINEERING DESIGN AND ANALYSIS. 2.0 Semester Hrs.
(I, II) In this graduate-level course, students will participate in a directed team-based project learning through planning, designing, and analyzing a large, modern data center for an industry- or government-relevant application. The course will build on content learned in pre-requisite courses on an Introduction to Data Center Engineering and on Data Center Infrastructure Management. Students will collaborate in multi-disciplinary teams to develop and present the design and analysis of a large, modern data center design for an industry or government application. 2 hours seminar; 2 semester hours.

Geochemistry

Degrees Offered

- Professional Masters in Environmental Geochemistry
- Master of Science (Geochemistry)
- Doctor of Philosophy (Geochemistry)

Program Description

The Graduate Program in Geochemistry is an interdisciplinary program with the mission to educate students whose interests lie at the intersection of the geological and chemical sciences. The Geochemistry Program consists of two subprograms, administering two M.S. and Ph.D. degree tracks and one Professional Master's (non-thesis) degree program. The Geochemistry (GC) degree track pertains to the history and evolution of the Earth and its features, including but not limited to the chemical evolution of the crust and mantle, geochemistry of energy and mineral resources, aqueous geochemistry and fluid-rock/fluid-mineral interactions and chemical mineralogy. The Environmental Biogeochemistry (EBGC) degree track pertains to the coupled chemical and biological processes of Earth's biosphere, and the changes in these processes caused by human activities.

Master of Science and Doctor of Philosophy

1. Geochemistry degree track

Prerequisites

Each entering student will have an entrance interview with members of the Geochemistry subprogram faculty. Since entering students may not be proficient in both areas, a placement examination in geology and/or chemistry may be required upon the discretion of the interviewing faculty. If a placement examination is given, the results may be used to establish deficiency requirements. Credit toward a graduate degree will not be granted for courses taken to fulfill deficiencies.

Requirements

The Master of Science (Geochemistry degree track) requires a minimum of 36 semester hours including:

Course work	24.0
Research credits	12.0
Total Semester Hrs	36.0

To ensure breadth of background, the course of study for the Master of Science (Geochemistry degree track) must include:

CHGC503	INTRODUCTION TO GEOCHEMISTRY	3.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
Master of Science (Geochemistry) students select three of the following (3.0):		
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
GEOL513	HYDROTHERMAL GEOCHEMISTRY	3.0
GEOL535	LITHO ORE FORMING PROCESSES	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
GEOL512	MINERALOGY AND CRYSTAL CHEMISTRY	3.0
CHGC514	GEOCHEMISTRY THERMODYNAMICS AND KINETICS	3.0
GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	3.0

In addition, all students must complete at least one laboratory course selected from the following (2.0):

GEGN530	CLAY CHARACTERIZATION	2.0
GEOL523	REFLECTED LIGHT AND ELECTRON MICROSCOPY	2.0

Master of Science (Geochemistry degree track) students must also complete an appropriate thesis, based upon original research they have conducted. A thesis proposal and course of study must be approved by the student's thesis committee before the student begins substantial work on the thesis research.

The requirement for the Doctor of Philosophy (Geochemistry degree track) program will be established individually by a student's thesis committee, but must meet the minimum requirements presented below. The Doctor of Philosophy (Geochemistry degree track) program will require a minimum of 72 credit hours beyond the Bachelor degree with a minimum of 40 course credit hours.

Students who enter the PhD program with a thesis-based Master's degree may transfer up to 36 semester hours in recognition of the course work and research completed for that degree. At the discretion of the student's Thesis Committee, up to 24 semester hours of previous graduate-level course work (at CSM or elsewhere) can be applied towards the course requirement of the Doctor of Philosophy (Geochemistry degree track) program.

Doctor of Philosophy (Geochemistry degree track) students must take:

CHGC503	INTRODUCTION TO GEOCHEMISTRY	3.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
CHGC514	GEOCHEMISTRY THERMODYNAMICS AND KINETICS	3.0
Students must also select two of the following (3.0):		
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
GEOL513	HYDROTHERMAL GEOCHEMISTRY	3.0
GEOL535	LITHO ORE FORMING PROCESSES	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
GEOL512	MINERALOGY AND CRYSTAL CHEMISTRY	3.0
GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	3.0

In addition, all students must complete at least one laboratory course selected from the following (2.0):

GEGN530	CLAY CHARACTERIZATION	2.0
GEOL523	REFLECTED LIGHT AND ELECTRON MICROSCOPY	2.0

Doctor of Philosophy (Geochemistry degree track) students must also complete an appropriate thesis, based upon original research they have conducted. A thesis proposal and course of study must be approved by the student's thesis committee before the student begins substantial work on the thesis research.

Master of Science (Geochemistry degree track) will be expected to give one pubic seminar on their research and Doctor of Philosophy (Geochemistry degree track) students are required to give at least one public seminar in addition to their thesis defense presentation.

2. Environmental Biogeochemistry (EBGC) degree track

Prerequisites

A candidate for an M.S. or Ph.D. in the EBGC degree track should have an undergraduate science or engineering degree with coursework including multivariable calculus, two semesters each of physics and chemistry, and one semester each of biology and earth science. Applicants who do not fulfill these requirements may still be admitted, but will need to undergo an entrance interview to establish deficiency requirements. Credit toward a graduate degree will not be given for undergraduate courses taken to fulfill deficiencies.

Requirements

Required Curriculum: A thesis proposal and thesis are required for all M.S. and Ph.D. degrees in the EBGC degree track. M.S. thesis advisors (or at least one co-advisor) must be members of the EBGC subprogram. Ph.D. thesis committees must have a total of at least four members. Ph.D. advisors (or at least one of two co-advisors) and one additional committee member must be members of the EBGC subprogram. M.S. students will be expected to give one public seminar on their research; Ph.D. students are required to give at least one in addition to their thesis defense presentation.

In addition, both M.S. and Ph.D. students in the EBGC degree track must complete the following coursework:

1. Two required classes:		
CHGC503	INTRODUCTION TO GEOCHEMISTRY	3.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
2. One chemistry-focused class, chosen from the following list:		
CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	3.0
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
CEEN551	ENVIRONMENTAL ORGANIC CHEMISTRY	3.0
3. One biology-focused class chosen from the following list:		
CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
CEEN562	ENVIRONMENTAL GEOMICROBIOLOGY	3.0
4. One earth science-focused class chosen from the following list		
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
(New class) Earth Surface Geochemistry		
5. One class focusing on analytical methods in environmental/ biogeochemistry chosen from several available, including:		
GEGN530	CLAY CHARACTERIZATION	2.0
(New class) Adv Geoenvironmental Anal		3.0

Total credits required for M.S.: 36

Total credits required for Ph.D.: 72 (at least 18 of coursework)

The student's thesis committee may specify additional course requirements and makes final decisions regarding transfer credits.

Comprehensive Examination

Doctor of Philosophy (Geochemistry) students in both degree tracks must take a comprehensive examination. It is expected that this exam will be completed within three years of matriculation or after the bulk of course work is finished, whichever occurs earlier. This examination will be administered by the student's thesis committee and will consist of an oral and a written examination, administered in a format to be determined by the thesis committee. Two negative votes in the thesis committee constitute failure of the examination.

In case of failure of the comprehensive examination, a re-examination may be given upon the recommendation of the thesis committee and approval of the Dean of Graduate Studies. Only one re-examination may be given.

Tuition

The Master of Science (Geochemistry) and Doctor of Philosophy (Geochemistry) programs have been admitted to the Western Regional Graduate Program. This entity recognizes the Geochemistry Program as unique in the region. Designation of the Geochemistry Program by Western Regional Graduate program allows residents of western states to enroll in the program at Colorado resident tuition rates. Eligible states include Alaska, Arizona, California ,Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, South Dakota, Utah, Washington and Wyoming.

Professional Masters in Environmental Geochemistry

Introduction

The Professional Masters in Environmental Geochemistry program is intended to provide:

1. an opportunity for CSM undergraduates to obtain, as part of a fifth year of study, a Master in addition to the Bachelor degree; and
2. additional education for working professionals in the area of geochemistry as it applies to problems relating to the environment.

This is a non-thesis Master degree program administered by the Environmental Biogeochemistry subprogram of the Geochemistry program, and may be completed as part of a combined degree program by individuals already matriculated as undergraduate students at CSM, or by individuals already holding undergraduate or advanced degrees and who are interested in a graduate program that does not have the traditional research requirement. The program consists primarily of coursework in geochemistry and allied fields with an emphasis on environmental applications. No research is required though the program does allow for independent study, professional development, internship, and cooperative experience.

Application

Undergraduate students at CSM must declare an interest during their third year to allow for planning of coursework that will apply towards the program. These students must have an overall GPA of at least 3.0.

Students majoring in other departments besides the Department of Geology and Geological Engineering and the Department of Chemistry and Geochemistry may want to decide on the combined degree program option earlier to be sure prerequisites are satisfied. Applicants other than CSM undergraduates who are applying for this non-thesis Master degree program must follow the same procedures that all prospective graduate students follow. However, the requirement of the general GRE may be waived.

Prerequisites

Each entering student will have an entrance interview with members of the Geochemistry faculty. Each department recognizes that entering students may not be proficient in both areas. A placement examination in geology and/or chemistry may be required upon the discretion of the interviewing faculty. If a placement examination is given, the results may be used to establish deficiency requirements. Credit toward a graduate degree will not be granted for courses taken to fulfill deficiencies.

Requirements

A minimum of 30 credit hours are required, with an overall GPA of at least 3.0. The overall course requirements will depend on the background of the individual, but may be tailored to professional objectives.

A 10 credit-hour core program consists of:

GEGN466	GROUNDWATER ENGINEERING *	3.0
CHGC503	INTRODUCTION TO GEOCHEMISTRY	3.0
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
Total Semester Hrs		9.0

In addition, 14 credit hours must be selected from the list below, representing the following core areas: geochemical methods, geographic information system, geological data analysis, groundwater engineering or modeling, hydrothermal geochemistry, isotope geochemistry, physical chemistry, microbiology, mineralogy, organic geochemistry, and thermodynamics. This selection of courses must include at least one laboratory course.

CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
CHGC555	ENVIRONMENTAL ORGANIC CHEMISTRY	3.0
CHGN503	ADV PHYSICAL CHEMISTRY I	4.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEGN581	ANALYTICAL HYDROLOGY	3.0
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	3.0
GEGN530	CLAY CHARACTERIZATION	2.0

Laboratory courses:

GEGNXXX	ADVANCED GEOENVIRONMENTAL ANALYSIS	3.0
GEGN530	CLAY CHARACTERIZATION	2.0

An additional 6 credit-hours of free electives may be selected to complete the 30 credit-hour requirement. Free electives may be selected from the course offerings of the Department of Geology and Geological Engineering, the Department of Chemistry and Geochemistry, or the Department of Civil and Environmental Engineering, and may also be independent study credits taken to fulfill a research cooperative, or other professional development experience. A course program will be designed in advanced through consultation between the student and an advisor from the Geochemistry Committee of the Whole.

CHGC503. INTRODUCTION TO GEOCHEMISTRY. 3.0 Semester Hrs.
(I) A comprehensive introduction to the basic concepts and principles of geochemistry, coupled with a thorough overview of the related principles of thermodynamics. Topics covered include: nucleosynthesis, origin of earth and solar system, chemical bonding, mineral chemistry, elemental distributions and geochemical cycles, chemical equilibrium and kinetics, isotope systematics, and organic and biogeochemistry. Prerequisite: Introductory chemistry, mineralogy and petrology. 3 hours lecture; 3 semester hours.

CHGC504. METHODS IN GEOCHEMISTRY. 2.0 Semester Hrs.
Sampling of natural earth materials including rocks, soils, sediments, and waters. Preparation of naturally heterogeneous materials, digestions, and partial chemical extractions. Principles of instrumental analysis including atomic spectroscopy, mass separations, and chromatography. Quality assurance and quality control. Interpretation and assessment of geochemical data using statistical methods. Prerequisite: Graduate standing in geochemistry or environmental science and engineering. 2 hours lecture; 2 semester hours.

CHGC505. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGN403,
(II) 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. Meets with CHGN403. CHGN403 and CHGC505 may not both be taken for credit. Prerequisites: GEGN101, CHGN122 and CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGC506. WATER ANALYSIS LABORATORY. 2.0 Semester Hrs.
Instrumental analysis of water samples using spectroscopy and chromatography. Methods for field collection of water samples and field measurements. The development of laboratory skills for the use of ICP-AES, HPLC, ion chromatography, and GC. Laboratory techniques focus on standard methods for the measurement of inorganic and organic constituents in water samples. Methods of data analysis are also presented. Prerequisite: Introductory chemistry, graduate standing. 3 hour laboratory, 1 hour lecture, 2 semester hours.

CHGC509. INTRODUCTION TO AQUEOUS GEOCHEMISTRY. 3.0 Semester Hrs.
Analytical, graphical and interpretive methods applied to aqueous systems. Thermodynamic properties of water and aqueous solutions. Calculations and graphical expression of acid-base, redox and solution-mineral equilibria. Effect of temperature and kinetics on natural aqueous systems. Adsorption and ion exchange equilibria between clays and oxide phases. Behavior of trace elements and complexation in aqueous systems. Application of organic geochemistry to natural aqueous systems. Light stable and unstable isotopic studies applied to aqueous systems. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours.

CHGC511. GEOCHEMISTRY OF IGNEOUS ROCKS. 3.0 Semester Hrs.
A survey of the geochemical characteristics of the various types of igneous rock suites. Application of major element, trace element, and isotope geochemistry to problems of their origin and modification. Prerequisite: Undergraduate mineralogy and petrology. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGC514. GEOCHEMISTRY THERMODYNAMICS AND KINETICS. 3.0 Semester Hrs.
(II) Fundamental principles of classical thermodynamics and kinetics with specific application to the earth sciences. Volume-temperature ? pressure relationships for solids, liquids, gases and solutions. Energy and the First Law, Entropy and the Second and Third Laws. Gibbs Free Energy, chemical equilibria and the equilibrium constant. Solutions and activity-composition relationships for solids, fluids and gases. Phase equilibria and the graphical representation of equilibira. Application of the fundamentals of kinetics to geochemical examples. Prerequisite: Introductory chemistry, introductory thermodynamics, mineralogy and petrology. 3 hours lecture, 3 semester hours. Offered in alternate years.

CHGC527. ORGANIC GEOCHEMISTRY OF FOSSIL FUELS AND ORE DEPOSITS. 3.0 Semester Hrs.
A study of organic carbonaceous materials in relation to the genesis and modification of fossil fuel and ore deposits. The biological origin of the organic matter will be discussed with emphasis on contributions of microorganisms to the nature of these deposits. Biochemical and thermal changes which convert the organic compounds into petroleum, oil shale, tar sand, coal and other carbonaceous matter will be studied. Principal analytical techniques used for the characterization of organic matter in the geosphere and for evaluation of oil and gas source potential will be discussed. Laboratory exercises will emphasize source rock evaluation, and oil-source rock and oil-oil correlation methods. Prerequisite: CHGN221, GEGN438. 2 hours lecture; 3 hours lab; 3 semester hours. Offered alternate years.

CHGC555. ENVIRONMENTAL ORGANIC CHEMISTRY. 3.0 Semester Hrs.
A study of the chemical and physical interactions which determine the fate, transport and interactions of organic chemicals in aquatic systems, with emphasis on chemical transformations of anthropogenic organic contaminants. Prerequisites: A course in organic chemistry and CHGN503, Advanced Physical Chemistry or its equivalent. Offered in alternate years. 3 hours lecture; 3 semester hours.

CHGC562. MICROBIOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs.
This course will cover the basic fundamentals of microbiology, such as structure and function of procaryotic versus eucaryotic cells; viruses; classification of micro-organisms; microbial metabolism, energetics, genetics, growth and diversity; microbial interactions with plants, animals, and other microbes. Additional topics covered will include various aspects of environmental microbiology such as global biogeochemical cycles, bioleaching, bioremediation, and wastewater treatment. Prerequisite: ESGN301. 3 hours lecture, 3 semester hours. Offered alternate years.

CHGC563. ENVIRONMENTAL MICROBIOLOGY. 2.0 Semester Hrs.
An introduction to the microorganisms of major geochemical importance, as well as those of primary importance in water pollution and waste treatment. Microbes and sedimentation, microbial leaching of metals from ores, acid mine water pollution, and the microbial ecology of marine and freshwater habitats are covered. Prerequisite: none. 1 hour lecture, 3 hours lab; 2 semester hours. Offered alternate years.

CHGC564. BIOGEOCHEMISTRY AND GEOMICROBIOLOGY. 3.0 Semester Hrs.
Designed to give the student an understanding of the role of living things, particularly microorganisms, in the shaping of the earth. Among the subjects will be the aspects of living processes, chemical composition and characteristics of biological material, origin of life, role of microorganisms in weathering of rocks and the early diagenesis of sediments, and the origin of petroleum, oil shale, and coal. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGC598. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGC599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGC698. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGC699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

Professors

Linda A. Figueroa, Civil and Environmental Engineering

Wendy J. Harrison, Geology and Geological Engineering

John McCray, Civil and Environmental Engineering

James F. Ranville, Chemistry

John R. Spear, Civil and Environmental Engineering

Bettina M. Voelker, Chemistry

Richard F. Wendlandt, Geology and Geological Engineering

Associate Professors

Christopher P. Higgins, Civil and Environmental Engineering

Thomas Monecke, Geology and Geological Engineering

Jonathan O. Sharp, Civil and Environmental Engineering

Assistant Professors

Alexander Gysi, Geology and Geological Engineering

Alexis Navarre-Sitchler, Geology and Geological Engineering

Professors Emeriti

John B. Curtis, Geology and Geological Engineering

Donald L. Macalady , Chemistry and Geochemistry

Patrick MacCarthy, Chemistry and Geochemistry

Samuel B. Romberger, Geology and Geological Engineering

Thomas R. Wildeman, Chemistry and Geochemistry

Associate Professors Emeriti

L. Graham Closs, Geology and Geological Engineering

E. Craig Simmons, Chemistry and Geochemistry

Hydrologic Science and Engineering

Degrees Offered

- Master of Science (Hydrology), Thesis option
- Master of Science (Hydrology), Non-thesis option
- Doctor of Philosophy (Hydrology)

Program Description

The Hydrologic Science and Engineering (HSE) Program is an interdisciplinary graduate program comprised of faculty from several different CSM departments.

The program offers programs of study in fundamental hydrologic science and applied hydrology with engineering applications. Our program encompasses groundwater hydrology, surface-water hydrology, vadose-zone hydrology, watershed hydrology, contaminant transport and fate, contaminant remediation, hydrogeophysics, and water policy/law.

HSE requires a core study of five formal graduate courses. Programs of study are interdisciplinary in nature, and coursework is obtained from multiple departments at CSM and is approved for each student by the student's advisor and thesis committee.

To achieve the Master of Science (M.S.) degree, students may elect the Non-Thesis option, based exclusively upon coursework and an independent study project or a designated design course, or the Thesis option. The thesis option is comprised of coursework in combination with individual laboratory, modeling and/or field research performed under the guidance of a faculty advisor and presented in a written thesis approved by the student's committee.

HSE also offers a combined baccalaureate/masters degree program in which CSM students obtain an undergraduate degree as well as a Thesis or Non-thesis M.S. in Hydrology. Please see the Combined Undergraduate/Graduate Programs sections in the Graduate (http://bulletin.mines.edu/graduate/programs) and Undergraduate (http://bulletin.mines.edu/undergraduate/undergraduateinformation/combinedundergraduategraduate) Catalogs for additional information.

To achieve the Doctor of Philosophy (Ph.D.) degree, students are expected to complete a combination of coursework and novel, original research, under the guidance of a faculty advisor and Doctoral committee, which culminates in a significant scholarly contribution to a specialized field in hydrologic sciences or engineering. Full-time enrollment is expected and leads to the greatest success, although part-time enrollment may be allowed under special circumstances. All doctoral students must complete the full-time, on-campus residency requirements (p. 16).

Currently, students will apply to the Hydrological Science & Engineering program through the Graduate School and be assigned to the HSE participating department of the student's HSE advisor. Participating units include: Chemistry and Geochemistry, Civil & Environmental Engineering (CEE), Geology and Geological Engineering (GE), Geophysical Engineering, Humanities, Arts, and Social Sciences (HASS), Mechanical Engineering (ME), Mining Engineering (MN), and Petroleum Engineering (PE). HSE is part of the Western Regional Graduate Program (WICHE), a recognition that designates these programs as unique within the Western United States. An important benefit of this designation is that students from several western states are given the tuition status of Colorado residents. These states include Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming.

For more information on HSE curriculum please refer to the HSE website at hydrology.mines.edu.

Combined Degree Program Option

CSM undergraduate students have the opportunity to begin work on a M.S. degree in Hydrology while completing their Bachelor's degree. The CSM Combined Degree Program provides the vehicle for students to complete graduate coursework while still an undergraduate student. For more information please contact the HSE Program Coordinator Tim VanHaverbeke.

Program Requirements

MS Thesis: 30 credit hours total, consisting of 24 credit hours of coursework and 6 credit hours of thesis credit. Students must also write and orally defend a research thesis.

MS Non-Thesis: 30 credit hours total, consisting of 27 credit hours of coursework and 3 credit hours of independent study or completion of an approved 3 credit hour Design Course*.

Ph.D.: 72 total credit hours, consisting of coursework (at least 36 h post-baccalaureate), and research (at least 24 h). Students must also successfully complete qualifying examinations, write and defend a dissertation proposal, write and defend a doctoral dissertation, and are expected to submit the dissertation work for publication in scholarly journals.

Thesis & Dissertation Committee Requirements

Students must meet the general requirements listed in the graduate bulletin section *Graduate Degrees and Requirements*. In addition, the student's advisor or co-advisor must be an HSE faculty member. For M.S. thesis students, at least two committee members must be members of the HSE faculty. For doctoral students, at least 2 faculty on the committee must be a member of the HSE faculty. For PhD committee the required at-large member must meet two requirements: (1) be from a CSM department out side the student's home department and (2) not be a member of the HSE core faculty.

Prerequisites

- baccalaureate degree in a science or engineering discipline
- college calculus: two semesters required
- differential equations: one semester required
- college physics: one semester required
- college chemistry: two semesters required
- college statistics: one semester required

Note that some prerequisites may be completed in the first few semesters of the graduate program if approved by the HSE Director.

Required Curriculum

Students will work with their academic advisors and graduate thesis committees to establish plans of study that best fit their individual interests and goals. Each student will develop and submit a plan of study to their advisor during the first semester of enrollment. Doctoral students may transfer in credits from an earned M.S. graduate program according to requirements listed in the Graduate Degrees and Requirements (p. 37) section of the graduate bulletin, and after approval by the student's thesis committee.

Core Curriculum

Curriculum areas of emphasis consist of core courses, and electives. Core courses include the following:

GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN582	INTEGRATED SURFACE WATER HYDROLOGY	3.0
CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	3.0
CEEN584	SUBSURFACE CONTAMINANT TRANSPORT	3.0
or CEEN580	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	
GEGN585	FLUID MECHANICS FOR HYDROLOGY	2.0
Total Semester Hrs		14.0

If a student has completed a Fluid Mechanics course this core requirement will be waived once an HSE Waiver Form is approved.

An HSE seminar is also required and will typically have a 598 course number. These are one-credit reading and discussion seminars. PhD students are required to complete at least two during their studies, and M.S. students must complete one seminar. The seminar courses are taught nearly every semester, with different topics depending on the instructor.

Students who plan to incorporate hydrochemistry into their research may elect to replace CEEN550 with a two-course combination that includes an aqueous inorganic chemistry course (CHGC509) and an environmental organic chemistry course (CEEN511).

A grade of B- or better is required in all core classes for graduation.

For Non Thesis MS students, the following is a list of **Design Courses*** that may be completed in lieu of an Independent Study:

CEEN515	HILLSLOPE HYDROLOGY AND STABILITY	3.0
CEEN581	WATERSHED SYSTEMS MODELING	3.0
CEEN575	HAZARDOUS WASTE SITE REMEDIATION	3.0
CEEN584	SUBSURFACE CONTAMINANT TRANSPORT	3.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
GEGN584	FIELD METHODS IN HYDROLOGY	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0

Elective courses may be chosen from the approved list below or as approved by your advisor or thesis committee.

CEEN471	WATER AND WASTEWATER TREATMENT SYSTEMS ANALYSIS AND DESIGN	3.0
CEEN511	UNSATURATED SOIL MECHANICS	3.0
CEEN512	SOIL BEHAVIOR	3.0
CEEN515	HILLSLOPE HYDROLOGY AND STABILITY	3.0
CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
CEEN562	ENVIRONMENTAL GEOMICROBIOLOGY	3.0
CEEN570	WATER AND WASTEWATER TREATMENT	3.0
CEEN571	ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE	3.0
CEEN575	HAZARDOUS WASTE SITE REMEDIATION	3.0
CEEN581	WATERSHED SYSTEMS MODELING	3.0
CEEN582	MATHEMATICAL MODELING OF ENVIRONMENTAL SYSTEMS	3.0
CEEN611	MULTIPHASE CONTAMINANT TRANSPORT	3.0
GEGN470	GROUND-WATER ENGINEERING DESIGN	3.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN573	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEGN581	ANALYTICAL HYDROLOGY	3.0
GEGN584	FIELD METHODS IN HYDROLOGY	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
MATH530	STATISTICAL METHODS I	3.0
MATH531	STATISTICAL METHODS II	3.0
MATH532	SPATIAL STATISTICS	3.0
EBGN510	NATURAL RESOURCE ECONOMICS	3.0
HASS588	WATER POLITICS AND POLICY	3.0

Directors

Jonathan (Josh) Sharp, HSE Director, Civil & Environmental Engineering

Alexis Sitchler, HSE Associate Director, Geology & Geological Engineering

Department of Chemistry and Geochemistry

James Ranville, Professor

Bettina Voelker, Professor

Department of Civil & Environmental Engineering

Christopher Higgins, Associate Professor

Terri Hogue, Professor

Tissa Illangasekare, Professor and AMAX Distinguished Chair

Ning Lu, Professor

Junko Munakata Marr, Associate Professor

John McCray, Professor & Department Head Civil & Environmental Engineering

Jonathan Sharp, Associate Professor

Kathleen Smits, Assistant Professor

John Spear, Professor

Department of Geology and Geological Engineering

David Benson, Professor

Reed Maxwell, Professor

Paul Santi, Professor

Kamini Singha, Professor

Alexis Sitchler, Assistant Professor

Wendy Zhou, Associate Professor and Graduate Dean

Department of Geophysics

John Bradford, Professor & Department Head of Geophysics

Brandon Dugan, Associate Professor

Yaoguo Li, Professor

Whitney Trainor-Guitton, Assistant Professor

Humanities, Arts and Social Sciences

Hussein Amery, Professor

Adrianne Kroepsch, Assistant Professor

Department of Mechanical Engineering

Nils Tilton, Assistant Professor

Department of Petroleum Engineering

Yu-Shu Wu, Professor

Mining Engineering

Rennie Kaunda, Assistant Professor

Economics & Business

Steven M. Smith, Assistant Professor

Interdisciplinary

Degrees Offered

- Master of Science (Interdisciplinary)
- Doctor of Philosophy (Interdisciplinary)

Program Description

In addition to its traditional degree programs, Mines offers innovative, interdisciplinary, research-based degree programs that fit the institutional role and mission, but cannot easily be addressed within a single discipline or degree program. Specialties offered under this option are provided for a limited time during which faculty from across campus come together to address relevant, timely, interdisciplinary issues. The Interdisciplinary Graduate Program is intended to:

1. Encourage faculty and students to participate in broadly interdisciplinary research,
2. Provide a mechanism by which a rigorous academic degree program may be tightly coupled to this interdisciplinary research, and
3. Provide a mechanism for faculty to develop and market test, timely and innovative interdisciplinary degree programs in the hope that, if successful, may become full-fledged, stand-alone degree programs in the future.

Program Requirements

Graduates of the Interdisciplinary Graduate Program must meet all institutional requirements for graduation and the requirements of the Specialty under which they are admitted.

Program Management

Overall management and oversight of the Interdisciplinary Degree Program is undertaken by a Program Oversight Committee consisting of the:

- Dean of Graduate Studies (Chair and Program Director),
- One Representative from the Faculty Senate,
- One Representative from Department Heads/Division Directors, and
- One Faculty Representative from each active Specialty Areas.

The role of the Oversight Committee is fourfold:

- Specialty *Oversight:* includes advising and assisting faculty in the creation of new Specialty areas, periodic Specialty review and termination of Specialties having exceed the allowed time limits,
- Specialty *Mentoring:* includes providing assistance to, and support of existing Specialties as they move toward applying for full degree status,
- *Program Advocacy:* includes promotion of program at the institutional level, and promotion, development and support of new Specialty areas with individual groups of faculty, and
- *Council Representation:* upon the advise of the directors of the individual Specialties offered, the Oversight Committee appoints an Interdisciplinary Degree program representative to Graduate Council.

Specialty Requirements and Approval Processes

Specialties must meet the following minimum requirements:

- Specialty area must be, within the context of Mines, interdisciplinary in nature. That is, expertise that would be reasonably expected to be required to deliver the specialty must span multiple degree programs at Mines.
- Faculty participating in the Specialty must be derived from no fewer than two separate home units.
- There must be a minimum of six tenure/tenure-track core faculty participating in the Specialty.

The package of materials to be reviewed for Specialty approval must, at a minimum, include the following items:

- Descriptive overview of Specialty degree area,
- List of participating Faculty and the Departments/Divisions in which they are resident,
- Name of Specialty to be included on the transcript,
- Listing and summary description of all Specialty degree requirements,
- A description of how program quality is overseen by participating Specialty faculty including the Admission to Candidacy process to be used within the Specialty,
- A copy of Bylaws (i.e., operating parameters that define how the Specialty is managed, how faculty participate, how admissions is handled, etc.) under which the Specialty and its faculty operate,
- A listing and justification for any additional resources needed to offer the Specialty, and
- A draft of the Graduate Bulletin text that will be used to describe the Specialty in the Interdisciplinary Degree section of Bulletin.

Materials for Specialty approval must be approved by all of the following groups. Faculty advancing a Specialty should seek approval from each group in the order in which they are presented below:

- Faculty and Department Heads/Division Directors of each of the departments/divisions contributing staffing to the Specialty,
- Interdisciplinary Program Oversight Committee,
- Graduate Council,
- Faculty Senate, and
- Provost.

Failure to receive approval at any level constitutes an institutional decision to not offer the Specialty as described.

Full-Fledged Degree Creation and Specialty Time Limits

Documentation related to specific program Specialties, as published in the Graduate Bulletin, includes the inception semester of the Specialty. For Specialties garnering significant enrollment and support by participating academic faculty, the Program Oversight Committee encourages the participating faculty to seek approval – both on campus, and through the Board of Trustees and DHE – for a stand alone degree program. Upon approval, all students still in the Specialty will be moved to the full-fledged degree program.

Admissions to all doctoral-level Specialties will be allowed for a maximum of 7 years after the Specialty inception date. Specialties may apply to the

Oversight Committee for a one-time extension to this time limit that shall not exceed 3 additional years. If successful, the Oversight Committee shall inform Graduate Council and the Faculty Senate of the extension.

Specialties

Operations Research with Engineering (ORwE) (initiated Fall, 2011)

Degrees Offered

- Doctor of Philosophy (Interdisciplinary); Specialty (Operations Research with Engineering)

Program Description

Operations Research (OR) involves mathematically modeling physical systems (both naturally occurring and man-made) with a view to determining a course of action for the system to either improve or optimize its functionality. Examples of such systems include, but are not limited to, manufacturing systems, chemical processes, socio-economic systems, mechanical systems (e.g., those that produce energy), and mining systems. The ORwE PhD Specialty allows students to complete an interdisciplinary doctoral degree in Operations Research with Engineering by taking courses and conducting research in eight departments/divisions: Applied Mathematics and Statistics, Electrical Engineering and Computer Sciences, Engineering and Computational Sciences, Civil and Environmental Engineering, Economics & Business, Mining Engineering, Mechanical Engineering, and Metallurgical & Materials Engineering.

Specialty Requirements

Doctoral students develop a customized curriculum to fit their needs. The degree requires a minimum of 72 graduate credit hours that includes course work and a thesis. Coursework is valid for nine years towards a Ph.D. degree; any exceptions must be approved by the Director of the ORwE program and student advisor.

Course Work

Core Courses	25.0
Area of Specialization Courses	12.0
Total Semester Hrs	37.0

Research Credits

At least 24.0 research credits. The student's faculty advisor and the doctoral thesis committee must approve the student's program of study and the topic for the thesis.

Qualifying Examination Process and Thesis Proposal

Upon completion of the core coursework, students must pass qualifying written examinations to become a candidate for the Ph.D. ORwE specialty. The proposal defense should be done within ten months of passing the qualifying exam.

Transfer Credits

Students may transfer up to 24.0 hours of graduate-level coursework from other institutions toward the Ph.D. degree subject to the restriction that those courses must not have been used as credit toward a Bachelor's degree. The student must have achieved a grade of B or better in all graduate transfer courses and the transfer must be approved by the student's Doctoral Thesis Committee and the Director of the ORwE program.

Unsatisfactory Progress

In addition to the institutional guidelines for unsatisfactory progress as described elsewhere in this bulletin: Unsatisfactory progress will be assigned to any full-time student who does not pass the following prerequisite and core courses in the first fall semester of study:

CSCI262	DATA STRUCTURES	3.0
EBGN555	LINEAR PROGRAMMING	3.0
MATH530	STATISTICAL METHODS I	3.0

and the following in the first spring semester of study:

CSCI406	ALGORITHMS	3.0
MEGN593	ENGINEERING DESIGN OPTIMIZATION	3.0

Unsatisfactory progress will also be assigned to any students who do not complete requirements as specified in their admission letter. Any exceptions to the stipulations for unsatisfactory progress must be approved by the ORwE committee. Part-time students develop an approved course plan with their advisor.

Prerequisites

Students must have completed the following undergraduate prerequisite courses with a grade of B or better:

CSCI261	PROGRAMMING CONCEPTS	3.0
CSCI262	DATA STRUCTURES	3.0

Students entering in the fall semester must have completed the Programming (CSCI261) prerequisite or equivalent. Students will only be allowed to enter in the spring semester if they have developed a course program such that they are able to take the qualifying exam within 3 semesters.

Required Course Curriculum

All Ph.D. students are required to take a set of core courses that provides basic tools for the more advanced and specialized courses in the program.

Core Courses		
CSCI/MATH406	ALGORITHMS	3.0
EBGN555	LINEAR PROGRAMMING	3.0
MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
MATH530	STATISTICAL METHODS I	3.0
MATH438	STOCHASTIC MODELS	3.0
MEGN593	ENGINEERING DESIGN OPTIMIZATION	3.0
Total Semester Hrs		18.0

Area of Specialization Courses		
Select Four of the Following:		12.0
EBGN528	INDUSTRIAL SYSTEMS SIMULATION	
or MATH542	SIMULATION	
or CSCI542	SIMULATION	

MTGN450/ MLGN550	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS
EBGN560	DECISION ANALYSIS
EENG517	THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS
EBGN655	ADVANCED LINEAR PROGRAMMING
CSCI562	APPLIED ALGORITHMS AND DATA STRUCTURES
MNGN536	OPERATIONS RESEARCH TECHNIQUES IN THE MINERAL INDUSTRY
MNGN538	GEOSTATISTICAL ORE RESERVE ESTIMATION
EBGN509	MATHEMATICAL ECONOMICS
EBGN575	ADVANCED MINING AND ENERGY ASSET VALUATION
MATH531	STATISTICAL METHODS II
xxxx598/698	Special Topics (Requires approval of the advisor and ORwE program director)

Materials Science

Degrees Offered

- Master of Science (Materials Science; thesis option or non-thesis option)
- Doctor of Philosophy (Materials Science)

Program Description

The interdisciplinary graduate program in Materials Science exists to educate students, with at least a Bachelor of Science degree in engineering or science, in the diverse field of Materials Science. This diversity includes the four key foundational aspects of Materials Science – materials properties including characterization and modeling, materials structures, materials synthesis and processing and materials performance – as applied to materials of a variety of types (i.e., metals, ceramics, polymers, electronic materials and biomaterials). The Materials Science graduate program is responsible for administering MS (thesis and non-thesis) and PhD Degrees in Materials Science.

This interdisciplinary degree program coexists along side strong disciplinary programs in Chemistry, Chemical and Biochemical Engineering, Mechanical Engineering, Metallurgical and Materials Engineering, Mining, and Physics. The student's graduate committee will have final approval of the course of study.

Fields of Research

- Advanced polymeric materials
- Alloy theory, concurrent design, theory-assisted materials engineering, and electronic structure theory
- Applications of artificial intelligence techniques to materials processing and manufacturing, neural networks for process modeling and sensor data processing, manufacturing process control
- Atomic scale characterization
- Atom Probe Tomography
- Biomaterials
- Ceramic processing, modeling of ceramic processing
- Characterization, thermal stability, and thermal degradation mechanisms of polymers
- Chemical and physical processing of materials, engineered materials, materials synthesis
- Chemical vapor deposition
- Coating materials and applications
- Computational condensed-matter physics, semiconductor alloys, first-principles phonon calculations
- Computer modeling and simulation
- Control systems engineering, artificial neural systems for senior data processing, polymer cure monitoring sensors, process monitoring and control for composites manufacturing
- Crystal and molecular structure determination by X-ray crystallography
- Electrodeposition
- Electron and ion microscopy
- Experimental condensed-matter physics, thermal and electrical properties of materials, superconductivity, photovoltaics
- Fuel cell materials
- Fullerene synthesis, combustion chemistry
- Heterogeneous catalysis, reformulated and alcohol fuels, surface analysis, electrophotography
- High temperature ceramics
- Intelligent automated systems, intelligent process control, robotics, artificial neural systems
- Materials synthesis, interfaces, flocculation, fine particles
- Mathematical modeling of material processes
- Mechanical metallurgy, failure analysis, deformation of materials, advanced steel coatings
- Mechanical properties of ceramics and ceramic composites
- High entropy alloys
- Mössbauer spectroscopy, ion implantation, small-angle X-ray scattering, semiconductor defects
- Nano materials
- Non-destructive evaluation
- Non-ferrous structural alloys
- Novel separation processes: membranes, catalytic membrane reactors, biopolymer adsorbents for heavy metal remediation of ground surface water
- Numerical modeling of particulate media, thermomechanical analysis
- Optical properties of materials and interfaces
- Phase transformations and mechanisms of microstructural change
- Photovoltaic materials and device processing
- Physical metallurgy, ferrous and nonferrous alloy systems
- Physical vapor deposition, thin films, coatings
- Power electronics, plasma physics, pulsed power, plasma material processing
- Processing and characterization of electroceramics (ferro-electrics, piezoelectrics, pyroelectrics, and dielectrics)
- Semiconductor materials and device processing
- Soft materials
- Solidification and near net shape processing
- Surface physics, epitaxial growth, interfacial science, adsorption
- Transport phenomena and mathematical modeling
- Weld metallurgy, materials joining processes
- Welding and joining science

COMBINED DEGREE OPTION

Mines undergraduate students have the opportunity to begin work on a M.S. non-thesis degree while concurrently completing their Bachelor's degree at Mines.

DUAL DEGREE PROGRAM OPtion

Students have the opportunity to earn two degrees with the dual degree option. Students complete coursework to satisfy requirements for both a non-thesis M.S. in Materials Science from the Colorado School of Mines and a M.S. of Physical Chemistry and Chemical Physics from the University of Bordeaux.

Program Requirements

Each of the three degree programs (non-thesis MS, thesis-based MS, and PhD) require the successful completion of three core courses for a total of 9 credit hours that will be applied to the degree program course requirements. Depending upon the individual student's background, waivers for these courses may be approved by the program director. In order to gain a truly interdisciplinary understanding of Materials Science, students in the program are encouraged to select elective courses from several different departments outside of the Materials Science program. Course selection should be completed in consultation with the student's advisor or program director as appropriate.

Listed below are the three required Materials Science core courses:

MLGN591	MATERIALS THERMODYNAMICS	3.0
MLGN592	ADVANCED MATERIALS KINETICS AND TRANSPORT	3.0
MLGN593	BONDING, STRUCTURE, AND CRYSTALLOGRAPHY	3.0
Total Semester Hrs		9.0

Master of Science (Thesis Option)

The Master of Science degree requires a minimum of 30.0 semester hours of acceptable coursework and thesis research credits (see table below). The student must also submit a thesis and pass the Defense of Thesis examination before the Thesis Committee.

COURSEWORK	Materials Science Courses *	18.0
MLGN707	Thesis Research Credits	12.0
Total Semester Hrs		30.0

* Must include 9.0 credit hours of core courses.

Master of Science (Non-Thesis Option with a case study)

The Master of Science degree requires a minimum of 30.0 semester hours of acceptable course work and case study credit including:

COURSEWORK	Materials Science Courses *	24.0
MLGN	Case Study	6.0
Total Semester Hrs		30.0

* Must include 9.0 credit hours of core courses.

Doctor of Philosophy

The Doctor of Philosophy degree requires a minimum of 72.0 hours of course and research credit including:

COURSEWORK	Materials Science Courses (minimum) *	24.0
MLGN707	Thesis Research Credits (minimum)	24.0

* Must include 9.0 credit hours of core courses.

A minimum of 15 course credits earned at CSM is required for the PhD degree. In exceptional cases, this 15 CSM course credit hour requirement can be reduced in part or in full through the written consent of the student's advisor, program director, and thesis committee.

Deficiency Courses

All doctoral candidates must complete at least 6 credit hours of background courses. This course requirement is individualized for each candidate, depending on previous experience and research activities to be pursued. Competitive candidates may already possess this background information. In these cases, the candidate’s Thesis Committee may award credit for previous experience. In cases where additional coursework is required as part of a student’s program, these courses are treated as fulfilling a deficiency requirement that is beyond the total institutional requirement of 72 credit hours.

PhD Qualifying Process

The following constitutes the qualifying processes by which doctoral students are admitted to candidacy in the Materials Science program.

Core Curriculum – The three required core classes must be completed in the first full academic year for all doctoral candidates. Students must obtain a grade of B- or better in each class to be eligible to take the qualifying examination at the end of the succeeding spring semester. If not allowed to complete the qualifying examination at the end of the spring semester, students will be discouraged from the PhD program and encouraged, rather, to finish with a Masters degree

PhD Qualifying Examination – A qualifying examination is given annually at the end of the spring semester under the direction of the Materials Science Graduate Affairs Committee. All first-year Materials Science PhD students are expected to successfully complete the qualifying examination to remain in good standing in the program. The examination covers material from the core curriculum plus a standard introductory text on Materials Science, such as "Materials Science and Engineering: An Introduction", by William Callister. If a student performs below the expectations of the Materials Science faculty on the written exam, they will be asked to complete a follow-up oral examination in the summer semester. The oral examination will be based on topics deemed to be deficient in the written examination. Satisfactorily completing the oral exam will allow the student to proceed with the PhD program. Students who perform below the expectations of the Materials Science faculty on the oral exam will not be allowed to continue with the PhD program.

PhD Thesis Proposal – A student’s PhD thesis committee administers a PhD Thesis Proposal defense. The PhD proposal defense should occur no later than the student's fourth semester. While the proposal itself should focus on the central topic of a student’s research efforts, during the proposal defense, candidates may expect to receive a wide range of questions from the Committee. This would include all manner of questions directly related to the proposal. Candidates, however, should also expect questions related to the major concept areas of Materials Science within the context of a candidate's research focus. The Committee formally reports results of the PhD proposal defense to the Materials Science Program Director using the Committee Reporting form developed by the Office of Graduate Studies.

Upon completion of these steps and upon completion of all required coursework, candidates are admitted to candidacy.

Following successful completion of coursework and the PhD qualifying process, candidates must also submit a thesis and successfully complete the PhD Defense of Thesis examination before the PhD Thesis Committee.

MLGN500. PROCESSING, MICROSTRUCTURE, AND PROPERTIES OF MATERIALS. 3.0 Semester Hrs.
(II) A summary of the important relationships between the processing, microstructure, and properties of materials. Topics include electronic structure and bonding, crystal structures, lattice defects and mass transport, glasses, phase transformation, important materials processes, and properties including: mechanical and rheological, electrical conductivity, magnetic, dielectric, optical, thermal, and chemical. In a given year, one of these topics will be given special emphasis. Another area of emphasis is phase equilibria. Prerequisite: none. 3 hours lecture; 3 semester hours.

MLGN501. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.
(I) Application of X-ray diffraction techniques for crystal and molecular structure determination of minerals, inorganic and organometallic compounds. Topics include the heavy atom method, data collection by moving film techniques and by diffractometers, Fourier methods, interpretation of Patterson maps, refinement methods, and direct methods. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

MLGN502. 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. (Graduate students in physics may register only for PHGN440.) Prerequisite: PH320. 3 hours lecture; 3 semester hours.

MLGN503. CHEMICAL BONDING IN MATERIALS. 3.0 Semester Hrs.
(I) Introduction to chemical bonding theories and calculations and their applications to solids of interest to materials science. The relationship between a material's properties and the bonding of its atoms will be examined for a variety of materials. Includes an introduction to organic polymers. Computer programs will be used for calculating bonding parameters. Prerequisite: none. 3 hours lecture; 3 semester hours.

MLGN504. SOLID STATE THERMODYNAMICS. 3.0 Semester Hrs.
(I) Thermodynamics applied to solid state reactions, binary and ternary phase diagrams, point, line and planar defects, interfaces, and electrochemical concepts. Prerequisites: none. 3 hours lecture; 3 semester hours.

MLGN505. MECHANICAL PROPERTIES OF MATERIALS. 3.0 Semester Hrs.
(I) Mechanical properties and relationships. Plastic deformation of crystalline materials. Relationships of microstructures to mechanical strength. Fracture, creep, and fatigue. Prerequisite: MTGN348. 3 hours lecture; 3 hours lab; 3/4 semester hours. *This is a 3 credit-hour graduate course in the Materials Science Program and a 4 credit-hour undergraduate-course in the MTGN program.

MLGN506. TRANSPORT IN SOLIDS. 3.0 Semester Hrs.
(II) Thermal and electrical conductivity. Solid state diffusion in metals and metal systems. Kinetics of metallurgical reactions in the solid state. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of even years only.).

MLGN509. SOLID STATE CHEMISTRY. 3.0 Semester Hrs.
(I) Dependence on 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: none. 3 hours lecture; 3 semester hours. Offered alternate years.

MLGN510. SURFACE CHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGN410,
(I) Introduction to colloid systems, capillarity, surface tension and contact angle, adsorption from solution, micelles and microemulsions, 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: DCGN209 or DCGN210. 3 hours lecture; 3 semester hours.

MLGN511. KINETIC CONCERNS IN MATERIALS PROCESSING I. 3.0 Semester Hrs.
Equivalent with EGGN555,
(I) Introduction to the kinetics of materials processing, with emphasis on the momentum, heat and mass transport. Discussion of the basic mechanism of transport in gases, liquids and solids. Prerequisite: MTGN352, MTGN361, MATH225 or equivalent. 3 hours lecture; 3 semester hours.

MLGN512. CERAMIC ENGINEERING. 3.0 Semester Hrs.
(II) Application of engineering principles to nonmetallic and ceramic materials. Processing of raw materials and production of ceramic bodies, glazes, glasses, enamels, and cements. Firing processes and reactions in glass bonded as well as mechanically bonded systems. Prerequisite: MTGN348. 3 hours. lecture; 3 semester hours.

MLGN513. PROBLEM SOLVING IN MATERIALS SCIENCE. 3.0 Semester Hrs.
(I) Review the theoretical aspects of various physical phenomena of major importance to materials scientists. Develop mathematical models from these theories, and construct quantitative solution procedures based on analytical and numerical techniques. Prerequisite: MATH225. 3 hours lecture; 3 semester hours.

MLGN515. ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS. 3.0 Semester Hrs.
(II) Survey of the electrical properties of materials, and the applications of materials as electrical circuit components. The effects of chemistry, processing, and microstructure on the electrical properties will be discussed, along with functions, performance requirements, and testing methods of materials for each type of circuit component. The general topics covered are conductors, resistors, insulators, capacitors, energy convertors, magnetic materials, and integrated circuits. Prerequisites: PHGN200; MTGN311 or MLGN501; MTGN412/MLGN512,. 3 hours lecture; 3 semester hours.

MLGN516. PROPERTIES OF CERAMICS. 3.0 Semester Hrs.
(II) A survey of the properties of ceramic materials and how these properties are determined by the chemical structure (composition), crystal structure, and the microstructure of crystalline ceramics and glasses. Thermal, optical, and mechanical properties of single-phase and multi-phase ceramics, including composites, are covered. Prerequisites: PHGN200, MTGN311 or MLGN501, MTGN412. 3 semester hours: 3 hours lecture.

MLGN517. SOLID MECHANICS OF MATERIALS. 3.0 Semester Hrs.
(I) Review mechanics of materials. Introduction to elastic and non-linear continua. Cartesian tensors and stresses and strains. Analytical solution of elasticity problems. Develop basic concepts of fracture mechanics. Prerequisite: EGGN320 or equivalent, MATH225 or equivalent. 3 hours lecture; 3 semester hours.

MLGN518. PHASE EQUILIBRIA IN CERAMICS SYSTEMS. 3.0 Semester Hrs.

(II) Application of one of four component oxide diagrams to ceramic engineering problems. Emphasis on refractories and glasses and their interaction with metallic systems. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MLGN519. NON-CRYSTALLINE MATERIALS. 3.0 Semester Hrs.

(I) An 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. Prerequisites: MTGN311 or MLGN501; MLGN512/ MTGN412. 3 hours lecture; 3 semester hours.

MLGN521. KINETIC CONCERNS IN MATERIAL PROCESSING II. 3.0 Semester Hrs.

(I, II) Advanced course to address the kinetics of materials processing, with emphasis in those processes that promote phase and structural transformations. Processes that involve precipitation, sintering, oxidation, solgel, coating, etc., will be discussed in detail. Prerequisite: MLGN511. 3 hours lecture; 3 semester hours.

MLGN523. APPLIED SURFACE AND SOLUTION CHEMISTRY. 3.0 Semester Hrs.

(II) Solution and surface chemistry of importance in mineral and metallurgical operations. Pre requisite: none. 3 semester hours. (Spring of odd years only.).

MLGN526. GEL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

An introduction to the science and technology of particulate and polymeric gels, emphasizing inorganic systems. Interparticle forces. Aggregation, network formation, percolation, and the gel transition. Gel structure, rheology, and mechanical properties. Application to solid-liquid separation operations (filtration, centrifugation, sedimentation) and to ceramics processing. Prerequisite: Graduate level status. 3 hours lecture; 3 semester hours. Spring of odd years only.

MLGN530. INTRODUCTION TO POLYMER SCIENCE. 3.0 Semester Hrs.

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. Prerequisite: CHGN221, MATH225, CHEN357. 3 hour lecture, 3 semester hours.

MLGN531. POLYMER ENGINEERING AND TECHNOLOGY. 3.0 Semester Hrs.

(II) This class provides a background in polymer fluid mechanics, polymer rheological response and polymer shape forming. The class begins with a discussion of the definition and measurement of material properties. Interrelationships among the material response functions are elucidated and relevant correlations between experimental data and material response in real flow situations are given. Processing operations for polymeric materials will then be addressed. These include the flow of polymers through circular, slit, and complex dies. Fiber spinning, film blowing, extrusion and co-extrusion will be covered as will injection molding. Graduate students are required to write a term paper and take separate examinations which are at a more advanced level. Prerequisite: CRGN307, EGGN351 or equivalent. 3 hours lecture; 3 semester hours.

MLGN535. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 3.0 Semester Hrs.

Equivalent with CBEN435,CBEN535,CHEN435,CHEN535,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. Prerequisite: none. 3 hours lecture; 3 semester hours.

MLGN536. ADVANCED POLYMER SYNTHESIS. 3.0 Semester Hrs.

(II) An advanced course in the synthesis of macromolecules. Various methods of polymerization will be discussed with an emphasis on the specifics concerning the syntheses of different classes of organic and inorganic polymers. Prerequisite: CHGN430, ChEN415, MLGN530. 3 hours lecture, 3 semester hours.

MLGN544. PROCESSING OF CERAMICS. 3.0 Semester Hrs.

(II) A description of the principles of ceramic processing and the relationship between processing and microstructure. Raw materials and raw material preparation, forming and fabrication, thermal processing, and finishing of ceramic materials will be covered. Principles will be illustrated by case studies on specific ceramic materials. A project to design a ceramic fabrication process is required. Field trips to local ceramic manufacturing operations are included. Prerequisites: MTGN311, MTGN331, and MTGN412/MLGN512. 3 hours lecture; 3 semester hours.

MLGN550. STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS. 3.0 Semester Hrs.

(I) An introduction to statistical process control, process capability analysis and experimental design techniques. Statistical process control theory and techniques will be developed and applied to control charts for variables and attributes involved in process control and evaluation. Process capability concepts will be developed and applied for the evaluation of manufacturing processes. The theory and application of designed experiments will be developed and applied for full factorial experiments, fractional factorial experiments, screening experiments, multilevel experiments and mixture experiments. Analysis of designed experiments will be carried out by graphical and statistical techniques. Computer software will be utilized for statistical process control and for the design and analysis of experiments. Prerequisite: none. 3 hours lecture, 3 semester hours.

MLGN552. INORGANIC MATRIX COMPOSITES. 3.0 Semester Hrs.

(I) An introduction to the processing, structure, properties and applications of metal matrix and ceramic matrix composites. Importance of structure and properties of both the matrix and the reinforcement and the types of reinforcement utilized, e.g., particulate, short fiber, continuous fiber, and laminates. Special emphasis will be placed on the development of properties such as electrical and thermal will also be examined. Prerequisite/Co-requisite: MTGN311, MTGN352, MTGN445/ MLGN505. 3 hours lecture; 3 semester hours (Summer of even years only.).

MLGN555. POLYMER AND COMPLEX FLUIDS COLLOQUIUM. 1.0 Semester Hr.

Equivalent with BELS555,CBEN555,CHEN555,CHGN555,
The Polymer and Complex Fluids Group at the Colorado School of Mines combines expertise in the areas of flow and field based transport, intelligent design and synthesis as well as nanomaterials and nanotechnology. A wide range of research tools employed by the group includes characterization using rheology, scattering, microscopy, microfluidics and separations, synthesis of novel macromolecules as well as theory and simulation involving molecular dynamics and Monte Carlo approaches. The course will provide a mechanism for collaboration between faculty and students in this research area by providing presentations on topics including the expertise of the group and unpublished, ongoing campus research. Prerequisites: none. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

MLGN561. TRANSPORT PHENOMENA IN MATERIALS PROCESSING. 3.0 Semester Hrs.

(II) Fluid flow, heat and mass transfer applied to processing of materials. Rheology of polymers, liquid metal/particles slurries, and particulate solids. Transient flow behavior of these materials in various geometries, including infiltration of liquids in porous media. Mixing and blending. Flow behavior of jets, drainage of films and particle fluidization. Surface-tension-, electromagnetic-, and bubble-driven flows. Heat -transfer behavior in porous bodies applied to sintering and solidification of composites. Simultaneous heat-and-mass-transfer applied to spray drying and drying porous bodies. Prerequisites: ChEN307 or ChEN308 or MTGN461. 3 hours lecture; 3 semester hours.

MLGN563. POLYMER ENGINEERING: STRUCTURE, PROPERTIES AND PROCESSING. 3.0 Semester Hrs.

(II) An introduction to the structure and properties of polymeric materials, their deformation and failure mechanisms, and the design and fabrication of polymeric end items. The molecular and crystallographic structures of polymers will be developed and related to the elastic, viscoelastic, yield and fracture properties of polymeric solids and reinforced polymer composites. Emphasis will be placed on forming techniques for end item fabrication including: extrusion, injection molding, reaction injection molding, thermoforming, and blow molding. The design of end items will be considered in relation to: materials selection, manufacturing engineering, properties, and applications. Prerequisite: MTGN311 or equivalent. 3 hours lecture; 3 semester hours.

MLGN565. MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES. 3.0 Semester Hrs.

(II) 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. Prerequisites: MTGN445 or MLGN505. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MLGN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CHEN569,EGGN569,MTGN569,
(II) Investigate fundamentals of fuel-call 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. Prerequisites: EGGN371 or ChEN357 or MTGN351 Thermodynamics I, MATH225 Differential Equations. 3 credit hours.

MLGN570. BIOCOMPATIBILITY OF MATERIALS. 3.0 Semester Hrs.

(II) Introduction to the diversity of biomaterials and applications through examination of the physiologic environment in conjunction with compositional and structural requirements of tissues and organs. Appropriate domains and applications of metals, ceramics and polymers, including implants, sensors, drug delivery, laboratory automation, and tissue engineering are presented. Prerequisites: ESGN 301 or equivalent. 3 hours lecture; 3 semester hours.

MLGN572. BIOMATERIALS. 3.0 Semester Hrs.

Equivalent with MTGN572,
(I) A broad overview on materials science and engineering principles for biomedical applications with three main topics: 1) The fundamental properties of biomaterials; 2) The fundamental concepts in biology; 3) The interactions between biological systems with exogenous materials. Examples including surface energy and surface modification; protein adsorption; cell adhesion, spreading and migration; biomaterials implantation and acute inflammation; blood-materials interactions and thrombosis; biofilm and biomaterials-related pathological reactions. Basic principles of bio-mimetic materials synthesis and assembly will also be introduced. 3 hours lecture; 3 semester hours.

MLGN583. PRINCIPLES AND APPLICATIONS OF SURFACE ANALYSIS TECHNIQUES. 3.0 Semester Hrs.

(II) Instrumental techniques for the characterization of surfaces of solid materials. Applications of such techniques to polymers, corrosion, metallurgy, adhesion science, micro-electronics. Methods of analysis discussed: X-ray photoelectron spectroscopy (XPS), auger electron spectroscopy (AES), ion scattering spectroscopy (ISS), secondary ion mass spectroscopy (SIMS), Rutherford backscattering (RBS), scanning and transmission electron microscopy (SEM, TEM), energy and wavelength dispersive X-ray analysis; principles of these methods, quantification, instrumentation, sample preparation. Prerequisite: B.S. in metallurgy, chemistry, chemical engineering, physics. 3 hours lecture; 3 semester hours. This course taught in alternate even numbered years.

MLGN589. MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.

A review of the thermodynamic principles of work, energy, entropy, free energy, equilibrium, and phase transformations in single and multi-component systems. Students will apply these principles to a broad range of materials systems of current importance including solid state materials, magnetic and piezoelectric materials, alloys, chemical and electrochemical systems, soft and biological materials and nanomaterials. Prerequisites: A 300 level or higher course in thermodynamics. 3 semester hours lecture, 3 semester hours.

MLGN591. MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.

(I) A review of the thermodynamic principles of work, energy, entropy, free energy, equilibrium, and phase transformations in single and multi-component systems. Students will apply these principles to a broad range of materials systems of current importance including solid state materials, magnetic and piezoelectric materials, alloys, chemical and electrochemical systems, soft and biological materials and nanomaterials. Prerequisites: A 300 level or higher course in thermodynamics. 3 semester hours lecture, 3 semester hours.

MLGN592. ADVANCED MATERIALS KINETICS AND TRANSPORT. 3.0 Semester Hrs.

(I) A broad treatment of homogenous and heterogeneous kinetic transport and reaction processes in the gas, liquid, and solid states, with a specific emphasis on heterogeneous kinetic processes involving gas/solid, liquid/solid, and solid/solid systems. Reaction rate theory, nucleation and growth, and phase transformations will be discussed. A detailed overview of mass, heat, and charge transport in condensed phases is provided including a description of fundamental transport mechanisms, the development of general transport equations, and their application to a number of example systems. Prerequisites: A 300 level or higher course in thermodynamics, introductory college chemistry, electricity and magnetism, differential equations. 3 semester hours.

MLGN593. BONDING, STRUCTURE, AND CRYSTALLOGRAPHY. 3.0 Semester Hrs.

(I) This course will be an overview of condensed matter structure from the atomic scale to the mesoscale. Students will gain a perspective on electronic structure as it relates to bonding, long range order as it relates to crystallography and amorphous structures, and extend these ideas to nanostructure and microstructure. Examples relating to each hierarchy of structure will be stressed, especially as they relate to reactivity, mechanical properties, and electronic and optical properties. Prerequisites: A 300 level or higher course in thermodynamics. 3 semester hours.

MLGN598. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MLGN599. CASE STUDY MATERIALS SCIENCE. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MLGN607. CONDENSED MATTER. 3.0 Semester Hrs.

(I) Principles and applications of the quantum theory of electronic in solids: structure and symmetry, electron states and excitations in metals; transport properties. Prerequisite: PHGN520 and PHGN440/MLGN502. 3 hours lecture; 3 semester hours.

MLGN625. MOLECULAR SIMULATION METHODS. 3.0 Semester Hrs.

(I Even Years), Principles and practice of modern computer simulation techniques used to understand solids, liquids, and gases. Review of the statistical foundation of thermodynamics followed by in-depth discussion of Monte Carlo and Molecular Dynamics techniques. Discussion of intermolecular potentials, extended ensembles, and mathematical algorithms used in molecular simulations. Prerequisites: graduate level thermodynamics (required), statistical mechanics (recommended). 3 semester hours.

MLGN634. ADVANCED TOPICS IN THERMODYNAMICS. 3.0 Semester Hrs.

Advanced study of thermodynamic theory and application of thermodynamic principles. Possible topics include stability, critical phenomena, chemical thermodynamics, thermodynamics of polymer solutions and thermodynamics of aqueous and ionic solutions. Prerequisite: none. 1 to 3 semester hours.

MLGN635. POLYMER REACTION ENGINEERING. 3.0 Semester Hrs.

This class is aimed at engineers with a firm technical background who wish to apply that background to polymerization production techniques. The class begins with a review of the fundamental concepts of reaction engineering, introduces the needed terminology and describes different reactor types. The applied kinetic models relevant to polymerization reaction engineering are then developed. Next, mixing effects are introduced; goodness of mixing and effects on reactor performance are discussed. Thermal effects are then introduced and the subjects of thermal runaway, thermal instabilities, and multiple steady states are included. Reactive processing, change in viscosity with the extent of reaction and continuous drag flow reactors are described. Polymer de-volatilization constitutes the final subject of the class. Prerequisites: CRGN518 or equivalent. 3 hours lecture; 3 semester hours.

MLGN648. CONDENSED MATTER II. 3.0 Semester Hrs.

(II) Principles and applications of the quantum theory of electronic and phonons in solids; phonon states in solids; transport properties; electron states and excitation in semiconductors and insulators; magnetism; superconductivity. Prerequisite: PHGN640/MLGN607. 3 hours lecture; 3 semester hours.

MLGN673. STRUCTURE AND PROPERTIES OF POLYMERS. 3.0 Semester Hrs.

This course will provide an understanding of structure- properties relations in polymeric materials. The topics include: phase separation, amorphous structures, crystalline structures, liquid crystals, glass-rubber transition behavior, rubber elasticity, viscoelasticity, mechanical properties of polymers, polymer forming processes, and electrical properties of polymers. Prerequisite: MLGN563. 3 hours lecture; 3 semester hours.

MLGN696. VAPOR DEPOSITION PROCESSES. 3.0 Semester Hrs.

(II) Introduction to the fundamental physics and chemistry underlying the control of vapor deposition processes for the deposition of thin films for a variety of applications, e.g.,corrosion/oxidation resistance, decorative coatings, electronic and magnetic thin films. Emphasis on the vapor deposition processes and the control of process variables rather than the structure and properties of the thin films. Prerequisites: MTGN351, MTGN461, or equivalent courses. 3 hours lecture; 3 semester hours.

MLGN698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MLGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MLGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Professors

John R. Berger, Department of Mechanical Engineering

Cristian Ciobanu, Department of Mechanical Engineering

Mark Eberhart, Department of Chemistry

Thomas Gennett, Department of Chemistry

Michael J. Kaufman, Department of Metallurgical and Materials Engineering, Dean of CASE

Daniel M. Knauss, Department of Chemistry

Stephen Liu , Department of Metallurgical and Materials Engineering, American Bureau of Shipping Endowed Chair of Metallurgical and Materials Engineering

Ryan P. O'Hayre, Department of Metallurgical and Materials Engineering, Materials Science Program Director

Ivar E. Reimanis, Department of Metallurgical and Materials Engineering, Herman F. Coors Distinguished Professor of Ceramic Engineering

Ryan Richards, Department of Chemistry

Angus Rockett, Department of Metallurgical and Materials Engineering

P. Craig Taylor, Department of Physics

Colin Wolden , Department of Chemical Engineering, Weaver Distinguished Professor

Kim Williams, Department of Chemistry

Associate Professors

Stephen G. Boyes, Department of Chemistry and Geochemistry

Brian P. Gorman, Department of Metallurgical and Materials Engineering

Timothy R. Ohno, Department of Physics

Corrine E. Packard, Department of Metallurgical and Materials Engineering

Alan Sellinger, Department of Chemistry

Neal Sullivan, Department of Mechanical Engineering

Eric Toberer, Department of Physics

Assistant Professors

Geoff L. Brennecka, Department of Metallurgical and Materials Engineering

Svitlana Pylypenko, Department of Chemistry

Aaron Stebner, Department of Mechanical Engineering

Garritt Tucker, Department of Mechanical Engineering

Shubham Vyas, Department of Chemistry

Yongan Yang, Department of Chemistry

Professors Emeriti

Thomas E. Furtak, Department of Physics

John Moore, Department of Metallurgical and Materials Engineering

Denis W. Readey, Department of Metallurgical and Materials Engineering, University Professor-Emeritus

Chester J. Van Tyne, Department of Metallurgical and Materials Engineering

Teaching Associate Professor

Gerald Bourne, Department of Metallurgical and Materials Engineering

Research Professors

Richard K. Ahrenkiel, Department of Metallurgical and Materials Engineering

William (Grover) Coors, Department of Metallurgical and Materials Engineering

Research Associate Professor

Vilem Petr, Department of Mining

Research Assistant Professor

David Diercks, Department of Metallurgical and Materials Engineering

Nuclear Engineering

Degrees Offered

- Master of Engineering (Nuclear Engineering)
- Master of Science (Nuclear Engineering)
- Doctor of Philosophy (Nuclear Engineering)

Program Description

The Nuclear Science and Engineering program at the Colorado School of Mines is interdisciplinary in nature and draws contributions from the Department of Chemistry, the Department of Civil and Environmental Engineering, the Department of Humanities, Arts & Social Sciences, the Department of Mechanical Engineering, the Department of Metallurgical and Materials Engineering, the Department of Physics, and the Division of Economics and Business. While delivering a traditional Nuclear Engineering course core, the School of Mines program in Nuclear Science and Engineering emphasizes the nuclear fuel life cycle. Faculty bring to the program expertise in all aspects of the nuclear fuel life cycle; fuel exploration and processing, nuclear power systems production, design and operation, fuel recycling, storage and waste remediation, radiation detection and radiation damage as well as the policy issues surrounding each of these activities. Related research is conducted in the Nuclear Science and Engineering Center.

Students in all three Nuclear Engineering degrees are exposed to a broad systems overview of the complete nuclear fuel cycle as well as having detailed expertise in a particular component of the cycle. Breadth is assured by requiring all students to complete a rigorous set of core courses. The core consists of a 13 credit-hour course sequence. The remainder of the course and research work is obtained from the multiple participating departments, as approved for each student by the student's advisor and the student's thesis committee (as appropriate).

The Master of Engineering degree is a non-thesis graduate degree intended to supplement the student's undergraduate degree by providing the core knowledge needed to prepare the student to pursue a career in the nuclear energy field. The Master of Science and Doctor of Philosophy degrees are thesis-based degrees that emphasize research.

In addition, students majoring in allied fields may complete a minor degree through the Nuclear Science and Engineering Program, consisting of 12 credit hours of coursework. The Nuclear Science and Engineering Minor programs are designed to allow students in allied fields to acquire and then indicate, in a formal way, specialization in a nuclear-related area of expertise.

Program Requirements

The Nuclear Science and Engineering Program offers programs of study leading to three graduate degrees:

Master of Engineering (M.E.)

Core courses	13.0
Elective core courses	12.0
Additional elective courses	9.0
Nuclear Science and Engineering Seminar	2.0
Total Semester Hrs	36.0

Master of Science (M.S.)

Core courses	13.0
Elective core courses	6.0
Nuclear Science and Engineering Seminar	2.0
Graduate research (minimum)	12.0
Graduate research or elective courses	3.0
Total Semester Hrs	36.0

M.S. students must complete and defend a research thesis in accordance with this Graduate Bulletin and the Nuclear Science and Engineering Thesis Procedures (http://nuclear.mines.edu/Student-Information). The student must complete the preparation and defense of a Thesis Proposal as described by the Nuclear Science and Engineering Proposal Procedures (http://nuclear.mines.edu/Student-Information) at least one semester before the student defends his or her M.S. thesis.

Doctor of Philosophy (Ph.D.)

Core courses	13.0
Elective core courses	12.0
Additional elective courses	9.0
Nuclear Science and Engineering Seminar	4.0
Graduate research (minimum)	24.0
Graduate research or elective courses	10.0
Total Semester Hrs	72.0

Ph.D. students must successfully complete the program's quality control process.

The Ph.D. quality control process includes the following:

- Prior to admission to candidacy, the student must complete all seven of the Nuclear Engineering required and elective core classes;
- Prior to admission to candidacy, the student must pass a qualifying examination in accordance with the Nuclear Science and Engineering Qualifying Exam Procedures (http://nuclear.mines.edu/Student-Information) for any of his or her seven core classes in which he or she did not receive a grade of B or better;
- Prior to admission to candidacy, a Ph.D. thesis proposal must be presented to, and accepted by, the student's thesis committee in accordance with the Nuclear Science and Engineering Proposal Procedures (http://nuclear.mines.edu/Student-Information); and
- The student must complete and defend a Ph.D. thesis in accordance with this Graduate Bulletin and the Nuclear Science and Engineering Thesis Procedures (http://nuclear.mines.edu/Student-Information).

Students seeking a Ph.D. in Nuclear Engineering are also generally expected to complete a thesis-based Master's degree in Nuclear Engineering or a related field prior to their admission to Ph.D. candidacy.

Thesis Committee Requirements

The student's thesis committee must meet the general requirements listed in the Graduate Bulletin section on Graduate Degrees and Requirements (http://bulletin.mines.edu/graduate/programs). In addition, the student's advisor or co-advisor must be an active faculty member of CSM's Nuclear Science and Engineering Program. For M.S. students, at least two, and for Ph.D. students, at least three, committee members must be faculty members of the Nuclear Science and Engineering Program and must come from at least two different departments. At least one member of the Ph.D. committee must be a faculty member from outside the Nuclear Science and Engineering Program.

Required Curriculum

In order to be admitted to the Nuclear Science and Engineering Graduate Degree Program, students must meet the following minimum requirements:

- baccalaureate degree in a science or engineering discipline from an accredited program
- mathematics coursework up to and including differential equations
- physics coursework up to and including courses in introductory nuclear physics (or equivalent)
- coursework in thermodynamics, heat transfer, and fluid flow (or equivalent)

Students who do not meet these minimum requirements may be admitted with specified coursework to be completed in the first semesters of the graduate program. Entering students without an appropriate nuclear engineering background will be advised to take introductory nuclear engineering coursework prior to starting the nuclear engineering core course sequence. These introductory courses will be selected in consultation with the student's graduate advisor.

All degree offerings within the Nuclear Science and Engineering program are based on a set of required and elective core courses. The required core classes are:

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
NUGN580	NUCLEAR REACTOR LABORATORY (taught in collaboration with the USGS)	3.0
NUGN585 & NUGN586	NUCLEAR REACTOR DESIGN I and NUCLEAR REACTOR DESIGN II	4.0
Total Semester Hrs		13.0

Additionally, students pursuing a Nuclear Engineering graduate degree must take a certain number of courses from the elective core (four for a M.E., two for a M.S. and three for a Ph.D.). The core electives consist of the following:

CEEN558	ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES	3.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
PHGN504	RADIATION DETECTION AND MEASUREMENT	3.0
CHGN511	APPLIED RADIOCHEMISTRY	3.0
MEGN592	RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN	3.0
NUGN506	NUCLEAR FUEL CYCLE	3.0

Students will select additional coursework in consultation with their graduate advisor and their thesis committee (where applicable). This additional coursework may include offerings from all of the academic units participating in the degree program: Applied Math and Statistics, Chemistry and Geochemistry, Civil and Environmental Engineering, Humanities, Arts, and Social Sciences, Mechanical Engineering, Metallurgical and Materials Engineering, and Physics. Through these additional courses, students gain breadth and depth in their knowledge the Nuclear Engineering industry.

Students seeking M.S. and Ph.D. degrees are required to complete the minimum research credit hour requirements ultimately leading to the completion and defense of a thesis. Research is conducted under the direction of a member of CSM's Nuclear Science and Engineering faculty and could be tied to a research opportunity provided by industry partners.

Graduate Seminar

Full-time graduate students in the Nuclear Science and Engineering Program are expected to maintain continuous enrollment in Nuclear Science and Engineering Seminar. Students who are concurrently enrolled in a different degree program that also requires seminar attendance may have this requirement waived at the discretion of the Program Director.

Nuclear Engineering Combined Degree Program Option

CSM undergraduate students have the opportunity to begin work on a M.E. or M.S. degree in Nuclear Engineering while completing their Bachelor's degree. The Nuclear Engineering Combined Degree Program provides the vehicle for students to use up to 6 credit hours of undergraduate coursework as part of their Nuclear Engineering Graduate Degree curriculum, as well as the opportunity to take additional graduate courses while completing their undergraduate degree. Students in the Nuclear Engineering Combined Degree Program are expected to apply for admission to the graduate program by the beginning of their Senior Year. For more information please contact the Nuclear Science and Engineering Program Director.

Minor Degree Programs

Students majoring in allied fields may choose to complete minor degree programs through the Nuclear Science and Engineering Program indicating specialization in a nuclear-related area of expertise. Minor programs require completion of 12 credit hours of approved coursework. Existing minors and their requirements are as follows:

Nuclear Engineering

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
NUGN580	NUCLEAR REACTOR LABORATORY	3.0
CEEN558	ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES	3.0
Total Semester Hrs		12.0

Nuclear Materials Processing

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
MTGN591	PHYSICAL PHENOMENA OF COATING PROCESSES	3.0

CEEN558	ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES	3.0
Total Semester Hrs		12.0

Nuclear Detection

PHGN422	NUCLEAR PHYSICS	3.0
NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
PHGN504	RADIATION DETECTION AND MEASUREMENT	3.0
NUGN580	NUCLEAR REACTOR LABORATORY	3.0
Total Semester Hrs		12.0

Nuclear Geoscience and Geoengineering

PHGN422	NUCLEAR PHYSICS	3.0
Select three of the following:		9.0
Nuclear and Isotope Geochemistry		
In-situ Mining		
Uranium Mining		
Total Semester Hrs		12.0

Program Director

Mark Jensen, Jerry and Tina Grandey University Chair in Nuclear Science and Engineering, Department of Chemistry

Department of Chemistry

Jenifer Braley, Assistant Professor

Mark Jensen, Professor and Jerry and Tina Grandey University Chair in Nuclear Science and Engineering

Department of Civil and Environmental Engineering

Linda Figueroa, Professor, Nuclear Science and Engineering Center Management Team Co-Chair

Department of Mechanical Engineering

Mark Deinert, Associate Professor

Andrew Osborne, Research Assistant Professor

Department of Metallurgical and Materials Engineering

Kip Findley, Associate Professor

Jeffrey King, Associate Professor

Ivar Reimanis, Professor and Herman F. Coors Distinguished Professor of Ceramic Engineering

Haitao Dong, Radiation Safety Officer

Timothy Debey, Research Associate, Geologic Survey TRIGA Reactor Manager

Department of Physics

Uwe Greife, Professor, Nuclear Science and Engineering Center Management Team Chair

Frederic Sarazin, Professor

Zeev Shayer, Research Professor

Division of Economics and Business

Roderick Eggert, Professor

Courses

NUGN505. NUCLEAR SCIENCE AND ENGINEERING SEMINAR. 1.0 Semester Hr.
(I, II) The Nuclear Science and Engineering Seminar provides a forum for Nuclear Engineering graduate students to present their research projects, participate in seminars given by Nuclear Science and Engineering professionals, and develop an enhanced understanding of the breadth of the nuclear engineering discipline. Prerequsite: gradaute standing. 1 hour seminar; 1 semester hour. Repeatable; maximum 2 hours granted towards M.S./M.E. Degree Requirements and 4 hours maximum granted towards Ph.D. Requirements.

NUGN506. NUCLEAR FUEL CYCLE. 3.0 Semester Hrs.
(I) An introduction to nuclear energy emphasizing the science, engineering, and policies underlying the systems and processes involved in energy production by nuclear fission. Students will acquire a broad understanding of nuclear energy systems framed in the context of the fuel used to power nuclear reactors. 3 hours lecture; 3 semester hours.

NUGN510. INTRODUCTION TO NUCLEAR REACTOR PHYSICS. 3.0 Semester Hrs.
(II) Bridges the gap between courses in fundamental nuclear physics and the neutronic design and analysis of nuclear reactors. Review of neutron energetics and reactions; nuclear cross sections; neutron induced fission; neutron life cycle, multiplication, and criticality; nuclear reactor kinetics and control; the diffusion approximation for neutron transport; simple reactor geometries and compositions; modeling and simulation of reactors. Prerequisite: PHGN422. 3 hours lecture; 3 semester hours.

NUGN520. INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS. 3.0 Semester Hrs.
(II) Bridges the gap between fundamental courses in thermodynamics, fluid flow, and heat transer and the thermal-hydraulic design and analysis of nuclear reactors. Provides a comprehensive introduction to the thermal-hydraulics of each of the major classes of nuclear reactors. Introduces the major thermal-hydraulic computational tools, passively safe reactor design, thermal-hydraulic transient analysis, and severe nuclear reactor accident analysis.

NUGN535. INTRODUCTION TO HEALTH PHYSICS. 3.0 Semester Hrs.
(I) Health physics evaluates effects of ionizing radiation on biological systems for the safe use of radiation and control of potential health hazards. The core concept is dosimetry, which relates the radiation absorbed externally and internally to a quantitative estimate of health effects. Other areas in health physics such as protection standards, regulations, and radiation diagnosis and therapy are all constructed on dosimetric methods.

NUGN580. NUCLEAR REACTOR LABORATORY. 3.0 Semester Hrs.
(I) Provides hands-on experience with a number of nuclear reactor operations topics. Reactor power calibration; gamma spectroscopy; neutron activation analysis; reactor flux and power profiles; reactor criticality; control rod worth; xenon transients and burnout; reactor pulsing. Taught at the USGS TRIGA reactor. Prerequisite: NUGN510. 3 hours laboratory; 3 semester hours.

NUGN585. NUCLEAR REACTOR DESIGN I. 2.0 Semester Hrs.
(I) Provides a basic understanding of the nuclear reactor design process, including: key features of nuclear reactors; nuclear reactor design principles; identification of design drivers; neutronic and thermal-hydraulic design of nuclear reactors; reactor safety considerations; relevant nuclear engineering computer codes. Prerequisite: NUGN510. 2 hours lecture; 2 semester hours.

NUGN586. NUCLEAR REACTOR DESIGN II. 2.0 Semester Hrs.
(II) Builds on the design experience obtained in NUGN586 to provide an in-depth understanding of the nuclear reactor design process. Prerequisites: NUGN585 (taken in the same academic year). 2 hours lecture; 2 semester hours.

NUGN590. COMPUTATIONAL REACTOR PHYSICS. 3.0 Semester Hrs.
(I) This course will provide an introduction to computational nuclear reactor physics. Students will understand the physics driving neutron cross sections and how they determined, and how neutron transport calculations are completed using Monte Carlo and finite difference methods. Students will learn how to write modular code using professional software engineering practices, and will have an introduction to the Serpent and MCNP family of transport codes. 3 hours lecture; 3 semester hours.

NUGN598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

NUGN599. INDEPENDENT STUDY IN NUCLEAR ENGINEERING. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

NUGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

NUGN699. INDEPENDENT STUDY IN NUCLEAR ENGINEERING. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

NUGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Quantitative Biosciences and Engineering

Program Description

The graduate program in quantitative biosciences and engineering brings together faculty across the Mines campus working on diverse areas of biology to educate students, with at least a Bachelor of Science degree in engineering or science, in the diverse field of biology. Biology deals broadly with life on this planet, the human organism and its health, and harnessing biological processes to produce fuels, chemicals, and consumer products. Thus, biology in general and human health and well-being in particular are important application areas for virtually all other areas of science, technology and engineering. This is reflected in the fact that any academic discipline exists today with a bio-prefix, such as biophysics, biochemistry, bioengineering, mathematical biology, computational biology, systems biology, structural biology, biomedicine, biomaterials, biomechanics, bioinformatics, biological chemistry, geobiology, environmental biology, microbiology to name just a few. Similarly, health is included in many labels, e.g. digital healthcare, health economics, health informatics. Educating students at the interfaces of biology, health and engineering with other disciplines is a primary goal of this program.

Many departments at Mines jointly administer this cross-departmental program in interdisciplinary biosciences. The program co-exists alongside strong disciplinary programs, in chemistry and geochemistry, chemical and biochemical engineering, physics, computer science, mathematics and statistics, mechanical engineering and metallurgical and materials engineering, civil and environmental engineering, economics, geology and geological engineering and geophysics, and thus draws from the strengths of these programs through close links and joint courses. For administrative purposes, the student will reside in the advisor's home academic department. The student's graduate committee will have final approval of the course of study.

Fields of Research

Research at Mines in this rapidly growing field currently includes but is not limited to the following general areas:

- Laser Design and Imaging
- Biofuels and Metabolic Engineering
- Omics and Systems Biology
- Environmental Toxicology and Microbiology
- Biosensors and Devices
- Biotechnology
- Biomechanics
- Biofluid mechanics
- Bioinformatics and Computational Biology
- Tissue Engineering & Biomaterials
- Physical Biochemistry
- Biophysics and Analytical Methodology Development
- Digital Healthcare
- Mathematical Biology

More than 45 faculty members across the CSM campus participate in this program, which will in the future also involve faculty of nearby collaborating institutions and scientists from the biotech/healthcare industry.

Program Requirements

For admission, students may enter with biology or health related undergraduate degrees of with a technical degree, e.g. in engineering, mathematics, or computer science. Ideally, students with a technical major will either have one of the biology related minors form Mines, or demonstrate the equivalent background, e.g., through a biology or health related minor at another institution. Current Mines undergraduate students have the option to apply to the Office of Graduate Studies for the 4+1 combined program while pursuing their undergraduate degree.

Each of the three degree programs (non-thesis MS, thesis-based MS, and PhD) require the successful completion of three mandatory core courses for a total of 10 credit hours.

BIOL5XX	CELL BIOLOGY AND BIOCHEMISTRY Course not yet created. See advisor for course numbers.	4.0
BIOL5XX	APPLIED BIOINFORMATICS Course not yet created. See advisor for course numbers.	3.0
BIOL5XX	SYSTEMS BIOLOGY Course not yet created. See advisor for course numbers.	3.0
Total Semester Hrs		10.0

List of Electives:

Students must also take different numbers of electives, as per the degree chosen (see below). The current list of available electives is shown here but is dynamic. We expect the number of graduate level electives to increase over the time as this and other bio-related programs on campus evolve and expand. This list will therefore be updated annually subject to approval by the program's curriculum committee.

CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN531	IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS	3.0
CBEN570	INTRODUCTION TO MICROFLUIDICS	3.0
CEEN501	LIFE CYCLE ASSESSMENT	3.0
CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
CEEN562	ENVIRONMENTAL GEOMICROBIOLOGY	3.0
CEEN566	MICROBIAL PROCESSES, ANALYSIS AND MODELING	3.0
CEEN570	WATER AND WASTEWATER TREATMENT	3.0
CHGN429	BIOCHEMISTRY II	3.0
CSCI562	APPLIED ALGORITHMS AND DATA STRUCTURES	3.0
CSCI575	MACHINE LEARNING	3.0
MATH572	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING	3.0
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS	3.0

MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
MEGN536	COMPUTATIONAL BIOMECHANICS	3.0
MEGN537	PROBABILISTIC BIOMECHANICS	3.0
MTGN570	BIOCOMPATIBILITY OF MATERIALS	3.0
MTGN572	BIOMATERIALS	3.0
PHGN433	BIOPHYSICS	3.0

Master of Science in Quantitative Biosciences and Engineering (Thesis Option)

Here, the student conducts an in-depth research project with one of the participating faculty members who are currently accepting masters degree students. The Master of Science degree requires a minimum of 30 semester hours of acceptable course work and thesis research credits. The student must also submit a thesis and pass the Thesis Defense examination before the Thesis Committee.

Core Courses	10.0
Electives	8.0
BIOL707 Research	12.0
Total Semester Hrs	30.0

Master of Science in Quantitative Biosciences and Engineering (Non-Thesis Option)

Here, the student can opt to conduct a case study instead of a full-fledged research project. The case studies can be chosen from projects provided by program faculty, local industry or academic partners. Students can also opt to enroll in further electives instead of conducting an independent study where this is more in line with their career goals. The Master of Science degree requires a minimum of 30 semester hours of acceptable course work and project credits.

Core Courses	10.0
Electives	14.0
BIOL599 Independent Study	6.0
Total Semester Hrs	30.0

Doctor of Philosophy in Quantitative Biosciences and Engineering

The Doctor of Philosophy degree requires a minimum of 72.0 hours of course and research credit including at least 24 credits in coursework and at least 24 credits in research:

Core Courses	10.0
Electives	14.0
BIOL707 Research	24.0
Electives or BIOL707 Research	24.0
Total Semester Hrs	72.0

Checklist

The program is interdisciplinary and it is therefore expected that there will be diverse backgrounds in the students admitted to this program. To ensure that all fundamental knowledge is adequately present, candidates may need to complete courses, which depend on the candidates' backgrounds. For example, a student with an experimental biology background needs to take programming courses. The courses are thus individualized for each candidate based on their previous experience and research activities to be pursued where applicable. Some candidates may already possess this background information. In such circumstances, the candidate's Thesis Committee may award credit for previous experience. These courses can be at the undergraduate level but do not count towards the 30 credits in the case of the Masters and 72 credits in case of the PhD degrees. Students with sufficient background can start taking graduate level classes counting towards the graduate degree in their junior year, but the majority will do so in their senior year. The program will be flexible given the expected diverse backgrounds of the students, and will offer bootcamp style activities at the beginning of each core class in order to account for the differences in backgrounds, where students from one background will help teach students with other backgrounds to acquire complementary skills.

PhD Qualifying Process

Core Curriculum – The three required core classes must be completed in the first two full academic years for all doctoral candidates, except where remedial classes or prerequisites need to be taken prior. Students must obtain a grade of B- or better in each class and have a cumulative GPA of 3.0 or higher to be eligible to take the qualifying examination at the end of the succeeding spring semester. If not allowed to complete the qualifying examination at the end of the spring semester, students will be discouraged from the PhD program and encouraged, rather, to finish with a Masters degree

PhD Qualifying Examination – All first-year Quantitative Biosciences and Engineering PhD students are expected to successfully complete the qualifying examination at the end of the first year to remain in good standing in the program. The examination covers material from the core curriculum plus the theoretical background of their chosen area of research. If a student performs below the expectations of the faculty administering the oral exam, a student may need to finish with a Masters degree.

PhD Thesis Proposal – A student's PhD thesis committee administers the PhD Thesis Proposal defense. The PhD proposal defense should occur no later than the student's fourth semester. While the proposal itself should focus on the central topic of the student's research, during the proposal defense, candidates may expect to receive a wide range of questions from the Committee. This would include all manner of questions directly related to the proposal. Candidates, however, should also expect questions related to the major concept areas of Biology within the context of a candidate's research focus. The Committee formally reports the results of the PhD proposal defense to the Quantitative Biosciences and Engineering Program Director using the Committee Reporting form developed by the Office of Graduate Studies.

Upon completion of these steps and upon completion of all required coursework, candidates are admitted to candidacy. Following successful completion of coursework and the PhD qualifying process, candidates must also submit a thesis and successfully complete the PhD Defense of Thesis examination before the PhD Thesis Committee.

Combined Undergraduate/Graduate BS/MS Degree ("4+1")

The interdisciplinary biology degree programs will offer Mines undergraduate students the opportunity to begin work on the Graduate Degree while completing the requirements of their Bachelors Degree. The purpose is to give students a head start on graduate education and enable them to finish their Masters degree in one year after their Bachelors. Admission into a Combined Undergraduate/Graduate degree program is available only to current Mines undergraduate students. Students need to plan with their advisor what classes they would like to take and which prerequisites might be required in order to be able to fit the classes into their undergraduate curriculum.

BIOL598. SPECIAL TOPICS IN BIOLOGY. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

BIOL598. SPECIAL TOPICS IN BIOLOGY. 6.0 Semester Hrs.
(I, II, S) 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. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

BIOL599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

BIOL707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Advising Faculty

Joel Bach

Cecilia Diniz Behn

Steven Boyes

Nanette Boyle

John Bradford

Kevin Cash

Dylan Domaille

Christopher Higgins

Judith Klein-Seetharaman

Melissa Krebs

Amy Landis

Karin Leiderman-Gregg

Terry Lowe

David Marr

Keith Neeves

Steve Pankavich

Tony Petrella

Andrew Petruska

Matt Posewitz

James Ranville

Susanta Sarkar

Josh Sharp

Anne Silverman

Dendy Sloan

John Spear

Jeff Squier

Amadeu Sum

Brian Trewyn

Shubham Vyas

Hua Wang

Kim Williams

Xioli Zhang

Teaching Faculty

Linda Battalora

Kristine Csavina

Cynthia Norrgran

Josh Ramey

Jeffrey Schowalter

Space Resources

DEGREES OFFERED

- Certificate in Space Resources
- Master of Science in Space Resources (Non-Thesis)
- Doctor of Philosophy in Space Resources

Programs in Space Resources

This program is targeted to train recent graduates, as well as professionals interested in expanding their knowledge and skills to address the opportunities and challenges in space resource exploration and utilization. A 12-credit hour Post-Baccalaureate Certificate will require a set of three core courses (8 credit hours) taught by the program, a required 1-credit hour seminar course, and a technical elective chosen from a few selected key disciplines. These courses will also form a required set of core courses for the MS-NT program and for Ph.D. students entering the program without a relevant M.S. degree.

For the M.S. degree program, in addition to the 12 credit hours, an additional program design course will be required. Beyond that, students will take elective courses taught by departments from around the campus in one or more of five tracks as listed here:

- Remote Sensing, Prospecting, and Resource Assessment;
- Resource Extraction, Material Processing, and Refining;
- Power and Energy;
- Robotics, Autonomy, and Communications;
- Economics and Policy.

These tracks will facilitate students' focusing on critical technical topics in space resources including resource assessment, prospecting, materials extraction and processing, telecommunications, control and automation, power systems management, and techno-economic analysis. Students in the MS-NT and Ph.D. programs will have at least two project-oriented design and analysis courses, where students will practice design and system analysis in space systems for responsible exploration and stewardship of space resources. A student who completes a Ph.D. in Space Resources will possess all the training of a Master's degree holder with further specialization in one or more areas within the space resources field. The completed doctoral dissertation will make original contributions to the field.

The curricula for the graduate program in Space Resources will engage disciplines from all three Colleges at Mines – the College of Engineering and Computational Sciences (CECS), the College of Earth Resource Sciences and Engineering (CERSE), and the College of Applied Science and Engineering (CASE). Space Resources touches on physical sciences, engineering, and social science/policy fields and thus, interdisciplinary training and community is necessary to support a vibrant and successful degree program. As such, this program can only be successful as an interdisciplinary degree program with a Faculty Executive Committee of engaged members from many academic Departments.

The graduate program for Space Resources will include the following

- a 12-credit-hour post-baccalaureate Certificate in Space Resources offered online,
- a 30-credit Master of Science Non-Thesis (MS-NT) degree in Space Resources with some online course offerings for students to complete the degree remotely,
- a Ph.D. program in Space Resources requiring 36 credit hours of coursework, 36 credit hours of research, and the standard on-campus residency requirement.

Post-baccalaureate Certificate

This option will require the students to take 12 credit hours and involve course which will all be offered online. Currently, the online offerings will be in a synchronous manner to foster critical community building within the program. The courses will be offered in both Fall and Spring semesters.

Table 1 lists the courses that will comprise the curriculum for the 12-credit hour Certificate. The program faculty will offer the first four program specific courses synchronously online every semester.

The SPRS591 project course will be directed by a program faculty member, who will collaborate with partnering companies to develop non-proprietary design projects and economic feasibility studies for students to participate in and learn through a space-oriented design and/or analysis study. The SPRS503 course will be a required seminar course which can be attended remotely wherein students will listen to monthly distinguished speakers in the field and in off weeks present to each other about research and development in the Space Resources field related to their own work and interests.

Table 1 – Required courses for 12-credit-hour Post-Baccalaureate Certificate in Space Resources

SPRS501	SPACE RESOURCES FUNDAMENTALS	3.0
SPRS502	SPACE SYSTEMS ENGINEERING	3.0
SPRS503	SPACE RESOURCES GRADUATE SEMINAR	1.0
SPRS591	SPACE RESOURCES DESIGN AND ANALYSIS I	2.0
SPRS TECH	SPACE RESOURCES TECHNICAL ELECTIVE	3.0
Total Semester Hrs		12.0

Technical Elective 3.0 Elective from Table 3 (topics such as, planetary science, remote sensing, mineral economics, materials extraction, and electrochemical systems engineering)

The final course for the post-baccalaureate Certificate will be an elective wherein the student can take one of a few core technical electives related to Space Resources. The electives will be chosen from courses on topics such as planetary science, remote sensing, mineral economics, materials extraction, and electrochemical systems engineering. These elective courses are listed in Table 3. It is expected that some of these courses will be offered online in the future to ensure that students can complete the Certificate remotely.

Master of Science (Non-Thesis)

The Master of Science degree program will be exclusively non-thesis (MS-NT). The MS-NT degree program, coursework, will require 30 credit hours of coursework and start with the twelve credit hours tied to the Certificate program. The additional 18 credit hours for the MS-NT degree program are laid out in part in Table 2.

All of the courses identified as program core courses with the SPRS (MEGN) code in Table 1 and Table 2 will be offered online. We expect that many of the elective courses associated with this program will also eventually be offered synchronously online, so that students can complete the MS-NT degree remotely as part of the program. This may be done through hiring adjuncts to teach some of the courses or through adopting some of the existing offerings by current Mines faculty to synchronous online delivery or a synchronous /asynchronous combination. The process of getting the necessary number of courses and in particular electives and mathematical courses will take time as Mines moves to offering an increasing number of courses online. As such, the program will allow students at Mines to take courses with traditional in-class delivery during the period of transition. It is hoped that by the end of two-three years all students will be able to take all elective courses online.

The courses include a second-semester of project related courses in which the students go more into depth on design and analysis for space systems related to resource applications. This project may be extensions of projects from the first design course presented in Table 1. In addition, MS-NT degree students will be required to take a mathematical or computational methods course relevant to their field of interest/study (engineering, physics, economics, etc), and approved courses will be selected by the Faculty Executive Committee based on what mathematical or computational methods course will be available as online offerings from Mines. MS-NT degree students will also be expected to participate in the seminar course for zero-credit each semester they are enrolled in 2 or more courses toward their degree.

Table 2 – Technical electives for the 18-credit hours required in addition to 12 credit hours in Table 1 for a Master of Science Non-thesis degree in Space Resources

SPRS592	SPACE RESOURCES DESIGN AND ANALYSIS II	3.0
SPRS ENG/ECO	ADVANCED ENGINEERING OR ECONOMIC ANALYSIS COURSE	3.0
SPRS TECH	TECHNICAL ELECTIVE See Table 3	3.0
SPRS TECH	TECHNICAL ELECTIVE See Table 3	3.0
SPRS TECH	TECHNICAL ELECTIVE See Table 3	3.0
SPRS TECH	TECHNICAL ELECTIVE See Table 3	3.0
Total Semester Hrs		18.0

Advanced Engineering or Economic Analysis Course 3.0 - A course on mathematical analysis and/or numerical methods relevant for students' technical area of interest selected from existing courses offered in various departments.

Technical Electives - Three approved elective courses from Table 3 (with topic such as, planetary science, remote sensing, mineral economics, materials extraction, and electrochemical systems engineering)

The remaining 12 credit hours toward the MS-NT degree program will be chosen from a suite of courses tied to fundamental and applied topics relevant to space resources science, engineering, and economics that will eventually be offered online. Current courses proposed for these tracks are listed in Table 3 from the existing graduate bulletin and suggested by participating departments in the Space Resources program. The Faculty Executive Committee will work with course faculty, Departments, and interested adjunct professors from relevant industries that have a strong Colorado presence to move toward eventually creating online versions of these listed elective courses in order to support the remote students participating in the MS-NT program.

Table 3 – Elective courses for selected tracks to complete the MS-NT program in Space Resources.

Elective Track & Description and purpose
Remote Sensing, Prospecting, and Resource Assessment

GEGN401	MINERAL DEPOSITS	4.0
GEGN403	MINERAL EXPLORATION DESIGN	3.0
GEOL410	PLANETARY GEOLOGY	2.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN475	PLANETARY GEOPHYSICS	3.0
MNGN510	FUNDAMENTALS OF MINING AND MINERAL RESOURCE DEVELOPMENT	3.0
PHGN566	MODERN OPTICAL ENGINEERING	3.0

Resource Extraction, Material Processing, and Refining

CBEN550	MEMBRANE SEPARATION TECHNOLOGY	3.0
MNGN503	MINING TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT	3.0
MNGN514	MINING ROBOTICS	3.0
MNGN515	MINE MECHANIZATION AND AUTOMATION	3.0
MTGN531	THERMODYNAMICS OF METALLURGICAL AND MATERIALS PROCESSING	3.0
MTGN539	PRINCIPLES OF MATERIALS PROCESSING REACTOR DESIGN	3.0
PEGN508	ADVANCED ROCK PROPERTIES	3.0
PEGN517	DRILLING ENGINEERING PRINCIPLES	3.0
PEGN519	ADVANCED FORMATION EVALUATION	3.0
PEGN590	RESERVOIR GEOMECHANICS	3.0

Systems Engineering and Power

CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
EENG580	POWER DISTRIBUTION SYSTEMS ENGINEERING	3.0
EENG581	POWER SYSTEM OPERATION AND MANAGEMENT	3.0
MEGN561	ADVANCED ENGINEERING THERMODYNAMICS	3.0
MEGN569	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MEGN571	ADVANCED HEAT TRANSFER	3.0
MEGN593	ENGINEERING DESIGN OPTIMIZATION	3.0

Automation and Communications

CSCI572	COMPUTER NETWORKS II	3.0
CSCI575	MACHINE LEARNING	3.0
EENG525	ANTENNAS	3.0
EENG527	WIRELESS COMMUNICATIONS	3.0
MEGN544	ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL	3.0
MEGN545	ADVANCED ROBOT CONTROL	3.0

Economics and Policy

CEEN592	ENVIRONMENTAL LAW	3.0

CEEN594	RISK ASSESSMENT	3.0
EBGN504	ECONOMIC EVALUATION AND INVESTMENT DECISION METHODS	3.0
EBGN510	NATURAL RESOURCE ECONOMICS	3.0
EBGN535	ECONOMICS OF METAL INDUSTRIES AND MARKETS	3.0
EBGN560	DECISION ANALYSIS	3.0
MNGN501	REGULATORY MINING LAWS AND CONTRACTS	3.0
MNGN585	MINING ECONOMICS	3.0
PEGN530	ENVIRONMENTAL, ENERGY, AND NATURAL RESOURCES LAW	3.0

Ph.D. in Space Resources

The Ph.D. degree program requires 72 total credit hours, consisting of at least 36 credit hours of courses beyond the B.S. and at least 36 research credit hours. Ph.D. coursework beyond the M.S. degree program will not be restricted other than approved by the student's advisor and dissertation committee. Students who enter the Ph.D. program with an M.S. degree in a relevant engineering or science field will be expected to take at least 12 credit hours from the courses approved for the certificate and MS-NT program.

In accordance with other Ph.D. programs at Mines, students in the Space Resources Ph.D. degree program must successfully complete qualifying examinations, defend their written dissertation proposal, and write and defend a doctoral dissertation. Ph.D. research is aimed at fundamentally advancing the state of art in Space Resources. Ph.D. students are expected to submit the dissertation work for at least two archival publications in scholarly journals and present research findings in at least one professional conference. Students are also required to participate in the Space Resources seminar series both by attending seminars of distinguished speakers and by presenting their research on no less than an annual basis.

Ph.D. students in the Space Resources program will be advised by a faculty advisor affiliated with the program and by an interdisciplinary Doctoral committee, which must contain a majority of faculty affiliated with the program. The Ph.D. degree program culminates in a research dissertation that significant scholarly contribution to Space Resources as a field. Full-time enrollment is strongly encouraged and in accordance with all other graduate programs at Mines, the Ph.D. program will have a two-semester minimum residency requirement as described in the general section of the Graduate Bulletin.

Because of the interdisciplinary nature of Space Resources, there will be significant demands for flexibility in the Program's curriculum and faculty instructors to allow for students with a diverse range of backgrounds to enter and succeed in their targeted degree program. As such, the degree program is structured in such a way that students from the diverse backgrounds can expand their commitment as they progress through the program offerings.

Graduates from the Space Resources program with either an M.S. or Ph.D. degree will serve the growing needs of industry, government, and academia to develop and utilize space resources. Students, who complete the M.S. in Space Resources will have a broad, multi-disciplinary understanding of the overall flow of activities in the development of space resources, a high-level exposure to the different science and engineering disciplines involved in each phase and an understanding of the current state of affairs in space resource across academia, government and industry. A master's degree holder will be able to make immediate contributions to any government agency or company pursuing technical activities related to space resources. Ph.D. degree holders will be able to pursue post-doctoral positions in academia or contribute as a specialist in industry or government.

This interdisciplinary collaboration will be sustained through a governing Faculty Executive Committee, whose current members include tenured and tenure-track faculty in 10 different Departments, as well as core research faculty and a professor of practice in the Center for Space Resources at Mines. The Faculty Executive Committee will be led by Prof. Greg Jackson from Mechanical Engineering, who will serve as the interim Program Director by approval of the Provost.

SPRS501. SPACE RESOURCES FUNDAMENTALS. 3.0 Semester Hrs.
(I, II) This course provides an overview of the space resources field, including the current knowledge of available resources in the Solar System, extraction and utilization systems under development, economic and technical feasibility studies, legal and policy issues, and space exploration architectures that may be enabled by utilizing extraterrestrial resources in the near future. The course will build broad knowledge and develop confidence in problem solving in the space resources field. Prerequisite: Working knowledge of physical sciences, engineering fields, or economics at an advanced undergraduate level, with basic numerical analysis skills using a programming language or spreadsheet calculations. 3 hours lecture; 3 semester hours.

SPRS502. SPACE SYSTEMS ENGINEERING. 3.0 Semester Hrs.
(I, II) This course conveys the fundamentals of the systems engineering process as applied to large, complex space systems. It is intended for graduate students with various backgrounds. The students will become familiar with full scope of the systems engineering process from requirements definition, system design, system analysis through system verification. The process will be illustrated with real-world examples from current space systems with an emphasis on systems relevant to the development of space resources. Co-requisite: SPRS501. 3 hours lecture; 3 semester hours.

SPRS503. SPACE RESOURCES GRADUATE SEMINAR. 1.0 Semester Hr.
(I, II) The Space Resources Graduate Seminar will engage graduate students in the program with current research and developments related to space resources assessment, extraction, and utilization. The course, which will meet once a week, will provide students opportunities to engage with invited guest speakers who are industry, government, and academic leaders in the space resources field. Students will be asked to prepare a few short reports on research related to guest speaker seminars. Students will also prepare and deliver at least one technical presentation on their own work and/or that of others and lead a discussion on the topic of interest. This course will instill knowledge and confidence in the students to enable them to critique, articulate, and present concepts and relevant research and development in space resources. Co-requisite: SPRS501. 1 hour seminar; 1 semester hour.

SPRS591. SPACE RESOURCES DESIGN AND ANALYSIS I. 2.0 Semester Hrs.

(I, II) This course will provide graduate students in the program with directed team-based project learning by exploring the design, planning, and analysis of a mission, process, or systems for space resources assessment, extraction, and/or utilization. The course will meet formally twice a week for one hour and include a 10-15 minute discussion on relevant design aspects of space mission, processes, and/or systems. In this regard, it will build on content learned in the Space Resources Fundamental and Space Systems Engineering courses. Students will collaborate in multi-disciplinary teams of up to 5 students. Teams will be advised by the course instructor with significant industrial aerospace design experience and supported by faculty affiliated with the Space Resources program from relevant disciplines on campus. For teams with students in space resource economics, detailed economic analysis will be incorporated into those projects. Student teams will prepare a preliminary design, planning and analysis report early in the semester, one interim progress report, and a final report and project presentation. This course will guide the students and teach them good design and analysis practices and principles for missions and/or systems related to space resources. Co-requisites: SPRS501 and SPRS502. 2 hours lecture; 2 semester hours.

SPRS592. SPACE RESOURCES DESIGN AND ANALYSIS II. 3.0 Semester Hrs.

(I, II) The Space Resources Design and Analysis II course will provide graduate students in the MS-NT and Ph.D. degree programs in Space Resources with an independent design and analysis project. This project, which will be guided by the course instructor and a technical advisor, will enable the student to delve deeply into a particular system related to space resources prospecting, extraction, processing, and/or utilization. As much as possible, projects will be coordinated with industrial or government agency partners who are collaborating with the program. The course will involve weekly meetings with the course instructor and all students in the course where ideas are exchanged and progress discussed within the context of design and analysis principles learned in the pre-requisite course SPRS591. Students will be partnered with a faculty member affiliated with the Space Resources program. The student will prepare a final report and presentation to present to industry collaborators, space resources faculty, and other students in the course. The final report and/or presentation as appropriate will be converted to a journal or conference publication and/or presentation and resources from the program will support student costs for publishing and/or presenting the work. Prerequisite: SPRS591. 3 hours lecture; 3 semester hours.

Underground Construction and Tunnel Engineering

Degrees Offered

- Master of Science (Underground Construction and Tunnel Engineering), Thesis
- Master of Science (Underground Construction and Tunnel Engineering), Non-Thesis
- Doctor of Philosophy (Underground Construction and Tunnel Engineering)

Program Description

Underground Construction and Tunnel Engineering (UCTE) is an interdisciplinary field primarily involving civil engineering, geological engineering and mining engineering, and secondarily involving mechanical engineering, electrical engineering, geophysics, geology and others. UCTE deals with the design, construction, rehabilitation and management of underground space including caverns, shafts and tunnels for commercial, transportation, water and wastewater use. UCTE is a challenging field involving complex soil and rock behavior, groundwater conditions, excavation methods, construction materials, structural design flow, heterogeneity, and very low tolerance for deformation due to existing infrastructure in urban environments. Students pursuing a graduate degree in UCTE will gain a strong and interdisciplinary foundation in these topics.

The graduate degree program in UCTE is offered jointly by the Departments of Civil & Environmental Engineering (CEE), Geology & Geological Engineering (GEGN), and Mining Engineering (MN). UCTE faculty from each department are collectively responsible for the operations of the program. Participating students reside in one of these departments, typically the home department of their advisor.

Program coursework is selected from multiple departments at CSM (primarily CEE, GEGN, MN) and is approved for each student by the student's advisor and graduate committee. To achieve the M.S. degree, students may elect the non-thesis option based upon coursework and an independent study report tied to a required internship. Students may alternatively select the thesis option comprised of coursework and a research project performed under the guidance of a UCTE faculty advisor and presented in a written thesis approved by the student's thesis committee.

Ph.D. students are expected to complete a combination of coursework and novel, original research under the guidance of a UCTE faculty advisor and doctoral committee, which culminates in a significant scholarly contribution to a specialized field in UCTE. Full-time enrollment is encouraged and leads to the greatest success, although part-time enrollment is permissible for working professionals. All graduate students must complete the full-time, on-campus residency requirements described in the general section of the Graduate Catalog.

Program Requirements

M.S. Non-Thesis Option:
Coursework - 27.0 credit hours
Independent Study* - 3.0 credit hours
UCTE Seminar - 0.0 credit hours
Total Hours - 30.0

*M.S. non-thesis students are expected to complete an internship of approximately 3 months in duration (with a design firm, contractor, owner, equipment manufacturer, etc., and preferably on a UCTE job site). During the internship, each student completes a project-focused independent study related to an aspect of the internship. This is determined in consultation with the faculty advisor and internship sponsor. The independent study culminates with a project report and presentation. If an internship is not available or if the student has sufficient industry experience (determined by advisor and committee), the student may complete an industry-focused research project with a UCTE faculty member and industry partner. The research project culminates with a written report and final presentation.

M.S. Thesis Option:
Coursework - 24.0 credit hours
Research (minimum) - 6.0 credit hours
UCTE Seminar - 0.0 credit hours
Total Hours - 30.0

M.S. Thesis students must write and successfully defend a thesis report of their research. Ideally, M.S. thesis research should be industry focused and should provide value to industry UCTE practice.

Ph.D. Option
Coursework (beyond B.S. degree) - 42.0 credit hours
Independent Study* - 3.0 credit hours
Research (minimum) - 24.0 credit hours
UCTE Seminar - 0.0 credit hours
Total Hours - 72.0

Students must also successfully complete qualifying examinations, write and defend a dissertation proposal, and write and defend a doctoral dissertation. Ph.D. research is aimed at fundamentally advancing the state of the art in UCTE. Ph.D. students are expected to submit the dissertation work for publication in scholarly journals and disseminate findings throughout industry periodicals.

*Ph.D. students are expected to complete an internship of approximately 3 months in duration (with a design firm, contractor, owner, equipment manufacturer, etc., and preferably on a UCTE job site). If an internship is not available or if the student has sufficient industry experience (determined by advisor and committee), the student may complete an industry-focused research project via independent study with a UCTE faculty member and industry partner culminating with a written report and presentation.

Required Coursework

The following 19 credit hours are required for the M.S. (thesis and non-thesis) and Ph.D. degrees.

GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN561	UNDERGROUND CONSTRUCTION ENGINEERING LABORATORY 1	0.5
GEGN562	UNDERGROUND CONSTRUCTION ENGINEERING LABORATORY 2	0.5
CEEN513	ADVANCED GEOMATERIAL MECHANICS	4.0
CEEN523	UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND	4.0
MNGN504	UNDERGROUND CONSTRUCTION ENGINEERING IN HARD ROCK	3.0

MNGN509	CONSTRUCTION ENGINEERING AND MANAGEMENT	3.0

All M.S. and Ph.D. students are required to attend the UCTE seminar series (0 h); no registration is required.

M.S. non-thesis and Ph.D. students must complete an internship-related project, registering as an independent study in the home department of the faculty advisor (CEEN599, GEGN599, or MNGN599). This requirement may be waived for students with sufficient UC&T industry experience.

Elective Coursework

The following courses may be taken as electives to complete the M.S. and Ph.D. course requirements. Students may petition for other courses not listed below to count towards the elective requirement. In addition, M.S. or Ph.D. students may petition one of the following courses to substitute for a required course if one of the required courses is not offered during the student's course of study or if a student has sufficient background in one of the required course topics. All petitions must be made to the student's advisor and thesis committee.

CEEN415	FOUNDATION ENGINEERING	3.0
CEEN506	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN510	ADVANCED SOIL MECHANICS	3.0
CEEN541	DESIGN OF REINFORCED CONCRETE STRUCTURES II	3.0
CEEN599	INDEPENDENT STUDY	0.5-6
GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN563	APPLIED NUMERICAL MODELLING FOR GEOMECHANICS	3.0
GEGN573	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN581	ANALYTICAL HYDROLOGY	3.0
GEGN672	ADVANCED GEOTECHNICS	3.0
GEGN673	ADVANCED GEOLOGICAL ENGINEERING DESIGN	3.0
GEGN599	INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY	0.5-6
MNGN424	MINE VENTILATION	3.0
MNGN506	DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS	3.0
MNGN507	ADVANCED DRILLING AND BLASTING	3.0
MNGN524	ADVANCED MINE VENTILATION	3.0
MNGN590	MECHANICAL EXCAVATION IN MINING	3.0
MNGN599	INDEPENDENT STUDY	0.5-6

Thesis Committee Requirements

Students must meet the general committee requirements listed in the graduate bulletin. In addition, the student's advisor or co-advisor must be a UCTE faculty member. In the case that a student is co-advised, the co-advisor will serve as an additional committee member above and beyond the minimum committee requirements.

The committee for Ph.D. students enrolled in the UCTE degree program shall be composed of a minimum of four (4) faculty members:

- The student's advisor
- Two core UCTE faculty members representing two of three core UCTE departments (Civil Engineering, Geological Engineering, Mining Engineering)
- An "external" committee member, who has no connection to the student or their research (this member should not come from any of the three core UCTE departments, other than in exceptional circumstances); this member will chair the committee and must be a permanent CSM faculty member

Additional committee members may be added as appropriate, including off-campus representatives from industry and academia.

Given the interdisciplinary nature of the UCTE degree program, no more than two (2) of the four Ph.D. committee members can be from the same department.

Qualifying Exam Procedure

Students enrolled in the UCTE Ph.D. program are expected to have passed a qualifying exam by the end of their first year of study. This qualifying exam will be administered by a sub-committee of UCTE faculty. If a UCTE faculty member is serving on this sub-committee for the qualifying exam of a student they are advising, they will act as a non-voting member for that exam.

The intention of the qualifying exam is to evaluate the student's capacity to undertake Ph.D.-level research; this includes their ability to think critically, to apply core UCTE concepts to abstract problems, and to develop methods to test scientific hypotheses. The format of the exam will include a written component and an oral exam, approximately two hours in length. Prior to their oral exam, the student will be assigned two tasks:

- The student will be provided a research topic which has some relevance to their research, but is not directly related. The student will be required to submit an 8-10 page literature review on this topic to their committee twenty-four (24) hours prior to their oral exam. During the oral exam, the student will be asked questions related to their literature review.
- The student will be provided with four (4) questions which will represent a significant portion of their oral exam. These questions will be designed to assess the student's ability to consider analysis, design, and research questions critically. The core UCTE curriculum will serve as foundational knowledge for these questions. As the student's response will be oral (no written response to the questions will be submitted), the questions will require students to suggest problem solving approaches rather than to directly implement them. Based on the student's response to each question, follow-up questions will be asked.

If the student fails their first qualifying exam, they may be given an opportunity to attempt a second qualifying exam at the discretion of the committee who administered their first exam. If the student fails their second qualifying exam, they will not be admitted to Ph.D. candidacy.

Prerequisites

Students will enter the UCTE programs with a variety of backgrounds. Because the UCTE degrees are engineering degrees, the required prerequisite courses for the UCTE programs include basic engineering coursework, and specifically: (1) Strength of Materials or Mechanics of Materials, and (2) Fluid Mechanics. These prerequisite courses may be completed during the first semester of the graduate program if approved by the UCTE program faculty. The required coursework includes graduate level soil and rock mechanics as well as aspects of structural analysis and groundwater engineering. It is permissible for students to take these courses without having completed undergraduate courses in soil mechanics, rock mechanics, structural analysis and groundwater engineering. However, students may choose to complete undergraduate courses in these topics prior to or concurrently during enrollment in the required graduate program courses. The prerequisite courses do not count towards the requirements of the M.S. or Ph.D. degrees. Students should consult with UCTE faculty for guidance in this matter.

Director

Gabriel Walton, UCTE Director

Department of Civil & Environmental Engineering

Marte Gutierrez, J.R. Paden Distinguished Chair & Professor

Reza Hedayat, Assistant Professor

Panos Kiousis, Associate Professor

Michael Mooney, Grewcock Distinguished Chair & Professor

Shiling Pei, Assistant Professor

Department of Geology & Geological Engineering

Paul Santi, Professor

Gabriel Walton, Assistant Professor

Wendy Zhou, Associate Professor

Department of Mining Engineering

Ray Henn, Adjunct Professor

Rennie Kaunda, Assistant Professor

Eunhye Kim, Assistant Professor

Hugh Miller, Associate Professor

Priscilla Nelson, Department Head & Professor

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 (https://inside.mines.edu/POGO-Policies-Governance). 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 Campus Living Suite in Elm Hall.

For emphasis, the following policies are included or identified in this section:

- **Student Honor Code**
- **Policy on Academic Integrity/Misconduct**
- **Policy Prohibiting Gender-Based Discrimination, Sexual Harassment and Sexual Violence**
- **Unlawful Discrimination Policy**
- **Alcohol and Other Drugs Education and Prevention Policy**
- **Electronic Communications (E-mail) Policy**
- **Student Complaint Process**
- **Access to Student Records**
- **Posthumous Degree Awards**
- **Equal Opportunity, Equal Access, and Affirmative Action**
    - **Title IX @ Mines** (http://inside.mines.edu/POGO-Title-IX)
    - **SpeakUP@Mines**

Please note: Any policy or procedure updates during the term will be reflected in the Mines Policy Library (http://inside.mines.edu/POGO-Policies) 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

The Colorado School of 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. The 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

Academic misconduct is the intentional act of fraud, in which an individual seeks to claim credit for the work and efforts of another without authorization, or uses unauthorized materials or fabricated information in any academic exercise. Student Academic Misconduct arises when a student violates the principle of academic integrity. 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. As a guide, some of the more common forms of academic misconduct are noted below. This list is not intended to be all inclusive, but rather to be 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; 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; 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 a 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.

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, there needs to be a certain amount of consistency when handling such issues, so 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 in an appropriate fashion. The following procedure will be followed:

- The faculty member or thesis committee informs the student(s) of the allegations and charge of academic misconduct within 10 business days. This involves verbal communication with the student(s). The faculty member/thesis committee must have a meeting with the students(s) regarding the incident. This meeting allows the student the opportunity to give his/her perspective prior to an official decision being made. It also allows the faculty member to have a conversation with the student(s) to educate him/her on appropriate behavior.
- The circumstances of the academic misconduct dictate the process to be followed:
  - In the case of an allegation of academic misconduct associated with **regular coursework**, if after talking with the student(s), the faculty member feels the student is responsible for academic misconduct the faculty member should:
    - Assign a grade of "F" in the course to the student(s) that committed academic misconduct. A faculty member may impose a lesser penalty if the circumstances warrant, however the typical sanction is a grade of "F".
    - Contact the Dean of Students and his/her Department Head/Division Director to officially report the violation in writing within 5 business days of the charge of academic misconduct. The Dean of Students will communicate the final resolution in writing to the student, the faculty member, the Office of Academic Affairs, the Office of Graduate Studies and the student's advisor. The Dean of Students will also keep official records on all students with academic misconduct violations.
    - Prescribed disciplinary action for misconduct associated with regular coursework:
      - 1st Offense: A grade of "F" in the course.
      - 2nd Offense: A grade of "F" in the course, one-year academic suspension, and permanent notation of Academic Misconduct on the student's transcript.
  - 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), if after talking with the student, faculty member(s) feel the student is responsible for misconduct, the faculty should:
    - 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.
    - Contact the Dean of Students, Graduate Dean and the student's Department Head/Division Director to officially report the violation in writing within 5 business days of the charge of misconduct. The Dean of Students will communicate the final resolution in writing to the student, the faculty member, the Office of Graduate Studies, and the student's advisor. The Dean of Students will also keep official records on all students with academic misconduct violations.
  - 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 indicated 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.

- Students who suspect other students of academic misconduct should report the matter to the appropriate faculty member, the appropriate Department Head/Division/Program Director, the Dean of Undergraduate Students, the Dean of Graduate Students, or the Dean of Students. The information is then provided to the faculty member concerned.

4.0 APPEAL PROCESS FOR STUDENT ACADEMIC MISCONDUCT

For the most up-to-date version of this procedure and appeal request forms, please see the student section of the policy website (https://inside.mines.edu/POGO-Policies-Governance).

Policy Prohibiting Gender-Based Discrimination, Sexual Harassment and Sexual Violence

1.0 BACKGROUND AND PURPOSE

The Board of Trustees of the Colorado School of Mines ("the School" or "Mines") promulgates this policy pursuant to the authority conferred by §23-41-104(1), C.R.S., Title IX of the Education Amendments of 1972, 20 U.S.C. §§ 1681 *et seq.*, and its implementing regulations, 34 C.F.R. Part 106; Title IV and VII of the Civil Rights Act of 1964 (42 U.S.C. § 2000c and 42 U.S.C. §§ 2000e) and relevant sections of the Violence Against Women Reauthorization Act of 2013 (42 U.S.C. § § 14043e *et seq.*). This policy supersedes the Board of Trustee's Policy Prohibiting Sexual Harassment and shall govern if any other Mines policy conflicts with this policy's provisions. This policy does not preclude application or enforcement of other Mines policies. Nothing in this policy shall be construed to abridge academic freedom and inquiry, principles of free speech or Mines' educational purpose.

2.0 POLICY

Mines prohibits gender-based discrimination, sexual harassment or any form of sexual violence among the Mines campus community. Mines does not discriminate against any person because of gender, gender identity or gender expression. Mines will not tolerate any form of sexual harassment or sexual violence within the Mines campus community. Mines will not tolerate any form of retaliation against a community member for reporting complaints, or opposing gender-based discrimination, sexual harassment or sexual violence. Accordingly, the Board of Trustees adopts this policy prohibiting gender-based discrimination, sexual harassment and sexual violence.

In order to prevent incidents of gender-based discrimination, sexual harassment and sexual violence, Mines will: (1) develop, administer, maintain and update procedures to implement and resources to support this policy; (2) educate community members regarding policies and procedures related to prevention, reporting and investigation of gender-based discrimination, sexual harassment and sexual violence; (3) encourage community members to report actual and potential incidents of gender-based discrimination, sexual harassment and sexual violence; (4) take actions to prevent incidents of gender-based discrimination, sexual harassment and sexual violence from denying or limiting a community member's ability to participate in or benefit from Mines' educational and work programs; (5) make available timely services and resources for those who have been affected by gender-based discrimination, sexual harassment and sexual violence; (6) take actions to remedy any harm from incidents of gender-based discrimination, sexual harassment and sexual violence; and (7) take actions to prevent the recurrence of gender-based discrimination, sexual harassment and sexual violence.

Mines' Unlawful Discrimination policy shall govern all other forms of harassment or discrimination. No complainant shall be permitted to file a complaint under the Policy Prohibiting Gender-Based Discrimination, Sexual Harassment and Sexual Violence and any other Mines' complaint or grievance policy or procedure when the complaint or grievance arises of of an identical sets of facts.

3.0 DEFINITIONS

Gender-based discrimination involves treating a Mines community member unfavorably because of that person's gender, gender identity or gender expression. All allegations involving gender-based discrimination will be governed by this policy and its implementing procedures.

Sexual harassment is a form of gender discrimination. Sexual harassment, without regard to the gender of individuals involved, consists of unwelcome sexual advances, requests for sexual favors, and other verbal or physical conduct of a sexual nature when: (1) either explicitly or implicitly, submission to such conduct is made a term or condition of an individual's employment or educational endeavors; (2) submission to or rejection of such conduct is used as the basis for employment or educational decisions; or (3) such conduct has the purpose or effect of unreasonably interfering with an individual's work or academic performance, or creating an intimidating, hostile, or offensive working or educational environment. All allegations involving sexual harassment will be governed by this policy and its implementing procedures.

Sexual violence includes rape, sexual assault, sexual battery, sexual abuse and sexual coercion. In some cases, domestic violence, dating violence and stalking may also be forms of sexual violence. All allegations involving sexual violence will be governed by this policy and its implementing procedures.

For a more detailed discussion of the terms defined above, please see the Gender-Based Harassment, Sexual Harassment and Sexual Violence Complaint, Investigation, Resolution and Adjudication Procedure for Complaints Involving Student Behavior and the Gender-Based Harassment, Sexual Harassment and Sexual Violence Complaint, Investigation, Resolution and Adjudication Procedure for Complaints Involving Employee or Third-Party Behavior.

4.0 PROHIBITION AGAINST RETALIATION

This policy prohibits retaliation against any individual for raising an allegations of gender-based discrimination, sexual harassment or sexual violence, for cooperating in an investigation or another proceeding related to such allegations, or for opposing gender-based discrimination, sexual harassment or sexual violence. Complaints or instances of retaliation shall be addressed as separate potential violations of this policy.

5.0 SANCTIONS FOR VIOLATIONS

A violation of this policy may result in the imposition of sanctions. Sanctions may include, but are not limited to, the following: mandatory attendance at gender-based discrimination, sexual harassment and/or sexual violence awareness and prevention seminars; mandatory attendance at other training programs; oral reprimand and warning; written reprimand and warning; student probation, suspension, or expulsion; educational sanctions; restitution; suspension without pay; or termination of employment or appointment.

6.0 ENCOURAGEMENT OF REPORTING

Mines considers the health and safety of its community members to be of paramount importance. Therefore, Mines encourages community members to report all concerns regarding gender-based discrimination, sexual harassment and/or sexual violence in accordance with this policy and its procedures. There may be circumstances where community members are hesitant to report prohibited conduct because they fear it may result in other policy violations being discovered (such as drug use or underage alcohol consumption). Community members should always consider the health and safety of themselves and other Mines community members to be of primary concern and Mines shall review, if necessary, any other policy violations separately from allegations raised under this policy.

Contact for Complaints about Student, Employee, or Third-Party Behavior,

Karin Ranta-Curran (krcurran@mines.edu)**, Associate Vice President of Organizational Stratgey/Title IX Coordinator, 303-273-2558 | krcurran@mines.edu**
Additional contacts listed in the Title IX section below.

For a complete policy statement and the most up-to-date procedures, definitions and resources as well as reporting forms, please refer to the Policy Library Student policies (https://inside.mines.edu/POGO-Student). *This policy was promulgated by the Colorado School of Mines Board of Trustees on March 13, 1992. Amended by the Colorado School of Mines Board of Trustees on March 26, 1998. Amended by the Colorado School of Mines Board of Trustees on June 10, 1999. Amended by the Colorado School of Mines Board of Trustees on June 22, 2000. Amended by the Colorado School of Mines Board of Trustees on June 7, 2003. Amended by the Colorado School of Mines Board of Trustees on December 15, 2011. Amended by the Colorado School of Mines Board of Trustees August 29, 2014.*

Unlawful Discrimination Policy and Complaint Procedure

1.0. BACKGROUND AND PURPOSE

This policy is promulgated by the Board of Trustees pursuant to the authority conferred upon it by §23-41-104(1), C.R.S. (1999) in order to set forth a policy concerning unlawful discrimination at Mines. This policy shall supersede any previously promulgated Mines policy that is in conflict herewith.

2.0 UNLAWFUL DISCRIMINATION POLICY

Attendance and employment at Mines are based solely on merit and fairness. Discrimination on the basis of age, gender, race, ethnicity, religion, national origin, disability, sexual orientation, and military veteran status is prohibited. No discrimination in admission, application of academic standards, financial aid, scholastic awards, or any terms or conditions of employment shall be permitted. No discrimination in admission, application of academic standards, financial aid, scholastic awards, or any terms or conditions of employment shall be permitted. If a complaint of discrimination on the basis of gender arises, it shall be governed under Mines' Policy Prohibiting Gender-Based Discrimination, Sexual Harassment and Sexual Violence.

3.0 PERSONS WHO MAY FILE AN UNLAWFUL DISCRIMINATION COMPLAINT

An unlawful discrimination complaint may be filed by an individual described in one of the categories below:

A. Any member of the Mines campus community, including classified staff, exempt employees, and students as well as any applicant for employment or admission, who believes that he or she has been discriminated against by Mines, a branch of Mines, or another member of the Mines community on account of age, race, ethnicity, religion, national origin, disability, sexual orientation, or military veteran status;

B. Any person who believes that he or she has been threatened with or subjected t duress or retaliation by Mines, a branch of Mines, or a member of the Mines community as a result of (1) opposing any unlawful discriminatory practice; (2) filing a complaint hereunder; (3) representing a complainant hereunder; or (4) testifying, assisting, or participating in any manner in an investigation, proceeding, hearing, or lawsuit involving unlawful discrimination; or

C. The Associate Vice President for Human Resources or an attorney from the Office of Legal Services, if any of these individuals deem it to be in the best interest of Mines to do so.

4.0 CHOICE OF REMEDIES

No complainant shall be permitted to file an unlawful discrimination claim under the Mines Unlawful Discrimination Policy any any other complaint or grievance policy or procedures when the complaint or grievance arises out of an identical set of facts. In such a situation, a complainant shall be entitled to file his or her claim under the policy or procedure of his or her choice.

***For a complete policy statement** and the most up-to-date procedures, please see the policy website* (https://inside.mines.edu/POGO-Policies-Governance)*. Promulgated by the Mines Board of Trustees on March 13, 1992. Amended by the Mines Board of Trustees on June 10, 1999; Amended by the Mines Board of Trustees on June 22, 2000; Amended by the Mines Board of Trustees, June 7, 2003; Amended by the Mines Board of Trustees August 14, 2007; Amended by the Mines Board of Trustees August 29, 2014.*

Alcohol and Other Drugs Education and Prevention Policy

In compliance with the federal government's Drug Free Schools & Communities Act, there are community standards and potential consequences at the 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 (http://inside.mines.edu/POGO-Student). Also see the Residence Life Policies (http://inside.mines.edu/%5Cresidencelife.mines.edu/RSL-Policies) and the Annual Campus Security and Fire Safety Report (http://publicsafety.mines.edu) for more on programming and requirements.

Electronic Communications (E-mail) Policy

1.0 BACKGROUND AND PURPOSE

Communication to students at the 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 wide-spread 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 the 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 (https://inside.mines.edu/POGO-Policies-Governance)*,* 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 (http://inside.mines.edu/Registrars_Office) @ 303-273-3200 or registrar@mines.edu; or

Computing, Communications & Information Technologies (http://ccit.mines.edu) (CCIT) @ 303-273-3431 or complete a request form at the Mines Help Center (http://helpdesk.mines.edu).

Student Complaint Process

Students are consumers of services offered as part of their academic and co-curricular experience at the 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

Students at the Colorado School of Mines are protected by the Family Educational Rights and Privacy Act of 1974, as amended. This Act was designed to protect the privacy of education records, to establish the right of students to inspect and review their education records, and to provide guidelines for the correction of inaccurate or misleading data through informal and formal hearings. Students also have the right to file complaints with The Family Educational Rights and Privacy Act Office (FERPA) concerning alleged failures by the institution to comply with the Act. Copies of local policy can be found in the Registrar's Office. 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: 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)

Student Access to Records. The graduate student wishing access to his or her educational records will make a written request to the Graduate Dean. This request will include the student's name, date of request and type of record to be reviewed. It will be the responsibility of the Dean to arrange a mutually satisfactory time for review. This time will be as soon as practical but is not to be later than 30 business days from receipt of the request. The record will be reviewed in the presence of the Dean or designated representative. If the record involves a list including other students, steps will be taken to preclude the viewing of the other student name and information.

Challenge of the Record. If the student wishes to challenge any part of the record, the Dean will be so notified in writing. The Dean may then

1. remove and destroy the disputed document, or
2. inform the student that it is his decision that the document represents a necessary part of the record; and, if the student wishes to appeal,
3. convene a meeting of the student and the document originator (if reasonably available) in the presence of the Executive Vice President for Academic Affairs as mediator, whose decision will be final.

Destruction of Records. Records may be destroyed at any time by the responsible official if not otherwise precluded by law except that no record may be destroyed between the dates of access request and the viewing of the record. If during the viewing of the record any item is in dispute, it may not be destroyed.

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 FERPA (https://www.mines.edu/policy-library/wp-content/uploads/sites/87/2018/04/FERPA-Policy-2018-1.pdf) at Mines in the Registrar's pages.

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 the on the policy website (https://inside.mines.edu/POGO-Policies-Governance). 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.

Title IX @ Mines

Karin Ranta-Curran, Associate Vice President - Organizational Strategy/ Title IX Coordinator
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303.384.2558 | krcurran@mines.edu

Deputy Title IX Coordinators:

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Wellness Center, Golden, CO 80401
303.384.3260 | kschmalz@mines.edu

Jenn Mazzotta, Director of Student Activities, Involvement, & Leadership
Student Center E120
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Dixie Cirillo, Associate Director of Athletics
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303.273.3206 | dcirillo@mines.edu (dcirillo@mines.edu)

SpeakUP@Mines

Students and employees have an additional anonymous channel for reporting concerns through the Whistleblower Policy and the SpeakUP@Mines (http://speakup.mines.edu) 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 of the information can be found in the Compliance and Policy Office in Guggenheim Hall.

More information can be found on the Financial Aid website (http://inside.mines.edu/UserFiles/File/studentLife/financialAid/Consumer%20Information.pdf).

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Index