Mechanical Engineering

Program Description

The Mechanical Engineering Department offers a design-oriented, project-based undergraduate program that emphasizes fundamental engineering principles, with many courses providing hands-on and active learning experiences. Students receive a strong foundation in mechanical engineering disciplines and a working knowledge of modern engineering tools, e.g., design and manufacturing techniques. To explore the many opportunities as a mechanical engineer, students may choose a track, which provides depth in specific areas, e.g., automotive, aerospace, biomechanics, energy and manufacturing, among others. With over 80% of our students participating in industry-sponsored internships or research with our faculty, our graduates are well-prepared for a mechanical engineering career in a world of rapid technological change.

The program leading to the degree of Bachelor of Science in Mechanical Engineering is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

Bachelor of Science in Mechanical Engineering

The Mechanical Engineering program intentionally embeds professional and technical skills, e.g., working on teams, engineering design, technical communication and programming, throughout the Mechanical Engineering curriculum. Our project-based design spine is bookended by the first-year experience in Introduction to Design (EDNS151) and our multidisciplinary capstone experience (EDNS 491 & 492) in the senior year. Following their first year at Mines, our students enter our project-based design spine in the middle years (sophomore and junior years):

- MEGN200 Introduction to ME: Programming & Hardware Interface. This course has students utilizing Arduinos while learning to program and breadboard to respond to an open-ended design problem.
- MEGN201 Introduction to ME: Design & Fabrication. In this course, students learn to design in SolidWorks, create technical drawings, use GD&T, and fabricate components in our machine shop with manual and CNC equipment.
- MEGN 300 Instrumentation and Automation: This course teaches our students to use more advanced instrumentation to collect and interpret real engineering data. Students use the LabVIEW programming language to design and control their devices and experiments.
- MEGN301 Mechanical Integration & Design. In this course students utilize the skills from the previous three courses as well as other ME courses to design, build and test their solution to an open-ended design project. This semester-long project immerses students in the design process and utilizes Scrum process to respond to project milestones.

This project-based experience teaches design methodology and stresses the creative aspects of the mechanical engineering profession. The courses help prepare students for open-ended, industry-based projects in the senior design experience.

Additionally, students complete an advanced mechanical engineering core that includes fluid mechanics, thermodynamics, dynamics, heat transfer, numerical methods, machine design, finite element analysis, and manufacturing processes. This engineering core is complemented by courses and electives in Culture and Society (CAS), which elaborate on the societal and economic impact of engineering solutions in our world. Students also take four advanced technical electives and three additional free electives to explore specific areas of interest. If students want to gain depth in a particular area on mechanical engineering, they can align their four ME electives in one of our eight tracks: Aerospace, Automotive, Automation and Controls, Biomechanics, Energy, Manufacturing, Materials, and Nuclear Energy.

There are plenty of opportunities outside of the curriculum for students to explore their passions. We have active Mines Maker Space, Robotics Club, and Formula SAE student groups among the over 300 student groups on campus, where students engage with the community, arts, and the outdoors.

Program Educational Objectives (Bachelor of Science in Mechanical Engineering)

The Mechanical Engineering program contributes to the educational objectives described in the Mines' Graduate Profile and the ABET Accreditation Criteria. Accordingly, the Mechanical Engineering Program at Mines has established the following program educational objectives for the B.S. in Mechanical Engineering degree:

Within three to five years of completing their degree, graduates will be:

- Apply their Mechanical Engineering education as active contributors in the workforce or graduate school;
- Effectively communicate technical information in a diverse and globally integrated society;
- Demonstrate their commitment to continued professional development through training, coursework, and/or professional society involvement;
- Exemplify ethical and social responsibility in their professional activities.

Bachelor of Science in Mechanical Engineering Degree Requirements:

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<thead>
<tr>
<th>Course</th>
<th>Description</th>
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<td>Total Semester Hrs: 126.0</td>
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* Mechanical Engineering students are required to take three Mechanical Engineering elective courses. At least one of these courses must be from the Advanced Engineering Sciences list. The remaining must be from either the Advanced Engineering Sciences list or the Mechanical Engineering Electives list.

**Advanced Engineering Sciences:**

- MEGN351 FLUID MECHANICS 3.0
- MEGN381 MANUFACTURING PROCESSES 3.0
- MEGN481 MACHINE DESIGN 3.0
- MECH Mechanical Engineering 3.0
- ELECT Elective* 3.0

**Mechanical Engineering Electives:**

- CEEN401 LIFE CYCLE ASSESSMENT 3.0
- CEEN405 NUMERICAL METHODS FOR ENGINEERS 3.0
- CEEN406 FINITE ELEMENT METHODS FOR ENGINEERS 3.0
- CEEN433 MATRIX STRUCTURAL ANALYSIS 3.0
- EBGN321 ENGINEERING ECONOMICS 3.0
- EDNS401 PROJECTS FOR PEOPLE 3.0
- EENG389 FUNDAMENTALS OF ELECTRIC MACHINERY 4.0
- EENG390 ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID 3.0
- EENG417 MODERN CONTROL DESIGN 3.0
MEGN330 INTRODUCTION TO BIOMECHANICAL ENGINEERING 3.0
MEGN391 INTRODUCTION TO AUTOMOTIVE DESIGN 3.0
MEGN430 MUSCULOSKELETAL BIOMECHANICS 3.0
MEGN435 MODELING AND SIMULATION OF HUMAN MOVEMENT 3.0
MEGN436 COMPUTATIONAL BIOMECHANICS 3.0
MEGN441 INTRODUCTION TO ROBOTICS 3.0
MEGN454 ORBITAL MECHANICS 3.0
MEGN456 SPACE OPERATIONS AND MISSION DESIGN 3.0
MEGN466 INTRODUCTION TO INTERNAL COMBUSTION ENGINES 3.0
MEGN469 FUEL CELL SCIENCE AND TECHNOLOGY 3.0
MEGN485 MANUFACTURING OPTIMIZATION WITH NETWORK MODELS 3.0
MEGN486 LINEAR OPTIMIZATION 3.0
MEGN487 NONLINEAR OPTIMIZATION 3.0
MEGN488 INTEGER OPTIMIZATION 3.0
MEGN498 SPECIAL TOPICS IN MECHANICAL ENGINEERING (SPECIAL TOPICS) 1-6
MEGN5XX ANY 500-LEVEL MEGN COURSE 3.0
MTGN211 STRUCTURE OF MATERIALS 3.0
MTGN422 ENGINEERING ALLOYS 3.0
MTGN445 MECHANICAL PROPERTIES OF MATERIALS 3.0
MTGN464 FORGING AND FORMING 2.0
MTGN472 BIOMATERIALS I 3.0
MTGN475 METALLURGY OF WELDING 2.0
MTGN593 NUCLEAR MATERIALS SCIENCE AND ENGINEERING 3.0
NUGN520 INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS 3.0
PHGN300 PHYSICS III-MODERN PHYSICS I 3.0
PHGN350 INTERMEDIATE MECHANICS 4.0
PHGN419 PRINCIPLES OF SOLAR ENERGY SYSTEMS 3.0
PHGN466 MODERN OPTICAL ENGINEERING 3.0
AMFG401 ADDITIVE MANUFACTURING 3.0
AMFG421 DESIGN FOR ADDITIVE MANUFACTURING 3.0
AMFG422 LEAN MANUFACTURING 3.0
AMFG4XX Not Including 499 3.0
AMFG531 MATERIALS FOR ADDITIVE MANUFACTURING 3.0
AMFG511 DATA DRIVEN ADVANCED MANUFACTURING 3.0
CSCI200 FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN 3.0
CSCI306 SOFTWARE ENGINEERING 3.0
CSCI341 COMPUTER ORGANIZATION 3.0
CSCI404 ARTIFICIAL INTELLIGENCE 3.0
CSCI437 INTRODUCTION TO COMPUTER VISION 3.0
CSCI442 OPERATING SYSTEMS 3.0
CSCI470 INTRODUCTION TO MACHINE LEARNING 3.0
CSCI473 ROBOT PROGRAMMING AND PERCEPTION 3.0
EENG307 INTRODUCTION TO FEEDBACK CONTROL SYSTEMS 3.0
EENG310 INFORMATION SYSTEMS SCIENCE I 4.0
EENG385 ELECTRONIC DEVICES AND CIRCUITS 4.0
EENG386 FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS 3.0
EENG421 SEMICONDUCTOR DEVICE PHYSICS AND DESIGN 3.0
MATH324 STATISTICAL MODELING 3.0
MATH332 LINEAR ALGEBRA 3.0
MATH334 INTRODUCTION TO PROBABILITY 3.0
MATH335 INTRODUCTION TO MATHEMATICAL STATISTICS 3.0
MATH432 SPATIAL STATISTICS 3.0
MATH436 ADVANCED STATISTICAL MODELING 3.0
MEGN4XX Mechanical Tech Elective (not including 499 & required 400-level courses) 3.0
MATH454 COMPLEX ANALYSIS 3.0
MATH455 PARTIAL DIFFERENTIAL EQUATIONS 3.0
CSCI5XX Non-project and research credit
EENG5XX Non-seminar and research credit
FEGN5XX Non-project and research credit
MATH5XX Non-project and research credit

Major GPA

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

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

- CEEN241
- EDNS491
- EDNS492
- MEGN100 through MEGN699 inclusive

Tracks for me undergraduate program

Tracks in Mechanical Engineering offer an opportunity for ME undergrads to explore various topics in mechanical engineering in more depth. Students gain depth in the areas by focusing their ME Electives on four courses prescribed in each track. Each proposed track is defined below with one course required in the Advanced Engineering Science Elective and three courses required from the ME Elective courses. Note that undergraduate students are not required to align with a track. Tracks are suggestions for students to gain advanced knowledge in a subdiscipline area and are “transcriptable.”

Aerospace

Advanced Engineering Science Elective
MEGN451 AERODYNAMICS 3.0
ME Elective (select 3 courses)
MEGN414 MECHANICS OF COMPOSITE MATERIALS 3.0
MEGN453 AEROSPACE STRUCTURES 3.0
MEGN454 ORBITAL MECHANICS 3.0
MEGN455 AEROSPACE SYSTEMS ENGINEERING 3.0
MEGN456  SPACE OPERATIONS AND MISSION DESIGN  3.0
MEGN458  INTRO TO SPACE EXPLORATION AND RESOURCES  3.0

Automation & Controls
Advanced Engineering Science Elective
MEGN416  ENGINEERING VIBRATION  3.0
ME Elective (select 3 courses)
EENG307  INTRODUCTION TO FEEDBACK CONTROL SYSTEMS  3.0
EENG383  EMBEDDED SYSTEMS  4.0
EENG389  FUNDAMENTALS OF ELECTRIC MACHINERY  4.0
EENG411  DIGITAL SIGNAL PROCESSING  3.0
EENG417  MODERN CONTROL DESIGN  3.0
MEGN441  INTRODUCTION TO ROBOTICS  3.0
MEGN485  MANUFACTURING OPTIMIZATION WITH NETWORK MODELS  3.0
MEGN540  MECHATRONICS  3.0

Automotive
Advanced Engineering Science Elective
MEGN461  THERMODYNAMICS II  3.0
ME Elective (select 3 courses)
MEGN391  INTRODUCTION TO AUTOMOTIVE DESIGN  3.0
MEGN417  VEHICLE DYNAMICS & POWERTRAIN SYSTEMS  3.0
MEGN466  INTRODUCTION TO INTERNAL COMBUSTION ENGINES  3.0
New electives in electric vehicles coming soon.

Biomechanics
Advanced Engineering Science Elective
MEGN412  ADVANCED MECHANICS OF MATERIALS  3.0
or MEGN416  ENGINEERING VIBRATION  3.0
ME Elective (select 3 courses)
MEGN330  INTRODUCTION TO BIOMECHANICAL ENGINEERING  3.0
MEGN430  MUSCULOSKELETAL BIOMECHANICS  3.0
MEGN435  MODELING AND SIMULATION OF HUMAN MOVEMENT  3.0
MEGN436  COMPUTATIONAL BIOMECHANICS  3.0
MEGN441  INTRODUCTION TO ROBOTICS  3.0
MEGN531  PROSTHETIC AND IMPLANT ENGINEERING  3.0
MTGN472  BIOMATERIALS I  3.0
FEGN525  ADVANCED FEA THEORY & PRACTICE  3.0

Energy
Advanced Engineering Science Elective
MEGN461  THERMODYNAMICS II  3.0
ME Elective (select 3 courses)
Choose 1 of the following:
MEGN469  FUEL CELL SCIENCE AND TECHNOLOGY  3.0
MEGN466  INTRODUCTION TO INTERNAL COMBUSTION ENGINES  3.0
MEGN467  PRINCIPLES OF BUILDING SCIENCE  3.0
Choose 2 of the following courses or from above:
CBEN472  INTRODUCTION TO ENERGY TECHNOLOGIES  3.0
EENG389  FUNDAMENTALS OF ELECTRIC MACHINERY  4.0
EENG390  ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID  3.0
MEGN560  DESIGN AND SIMULATION OF THERMAL SYSTEMS  3.0
PHGN419  PRINCIPLES OF SOLAR ENERGY SYSTEMS  3.0
Combined Mechanical Engineering Baccalaureate and Masters Degrees

Mechanical Engineering offers a five year combined program in which students have the opportunity to obtain specific engineering skills supplemented with graduate coursework in mechanical engineering. Upon completion of the program, students receive two degrees, the Bachelor of Science in Mechanical Engineering and the Master of Science in Mechanical Engineering.

Admission into a graduate degree program as a Combined Undergraduate/Graduate degree student may occur as early as the first semester Junior year and must be granted no later than the end of registration the last semester Senior year. Students must meet minimum GPA admission requirements for the graduate degree.

Students are required to take an additional thirty credits for the M.S. degree. Up to nine of the 30 credits beyond the undergraduate degree requirements can be 400-level courses. The remainder of the courses will be at the graduate level (500-level and above). The Mechanical Engineering Graduate Bulletin provides detail into the graduate program and includes specific instructions regarding required and elective courses. Students may switch from the combined program, which includes a non-thesis Master of Science degree to a M.S. degree with a thesis option; however, if students change degree programs they must satisfy all degree requirements for the M.S. with thesis degree.

The Mines guidelines for Minor/ASI can be found in the Undergraduate Information section of the Mines Catalog.

Mechanical Engineering Areas of Special Interest (ASI) and Minor Programs

General Requirements

The Mechanical Engineering Department offers minor and ASI programs. Students who elect an ASI or minor, must fulfill all prerequisite requirements for each course in a chosen sequence. Students in the sciences or mathematics must be prepared to meet prerequisite requirements in fundamental engineering and engineering science courses. Students in engineering disciplines are better positioned to meet the prerequisite requirements for courses in the minor and ASI Mechanical Engineering program. (See Minor/ASI section of the Bulletin for all requirements for a minor/ASI at CSM.)

For an Area of Special Interest in Mechanical Engineering, the student must complete the following 12 credits hours:

1. Required Courses (choose three, 9 credits)
   - MEGN212 INTRODUCTION TO SOLID MECHANICS 3.0
   - MEGN315 DYNAMICS 3.0
   - MEGN351 FLUID MECHANICS 3.0
   - MEGN361 THERMODYNAMICS I 3.0

2. Tracks (choose one track):
   - Solid Materials Track (9 credits)
     - MEGN324 INTRODUCTION TO FINITE ELEMENT ANALYSIS 3.0
     - MEGN412 ADVANCED MECHANICS OF MATERIALS 3.0
     - MEGN416 ENGINEERING VIBRATION 3.0
   - Thermal-Fluids Track (9 credits)
     - MEGN451 AERODYNAMICS 3.0
     - MEGN461 THERMODYNAMICS II 3.0
     - MEGN471 HEAT TRANSFER 3.0

Biomechanical Engineering Minor

General Requirements

To obtain a Biomechanical Engineering Minor, students must take at least 11.0 credits from the courses listed below. Fundamentals of Biology I (CBEN110) and Introduction to Biomechanical Engineering (MEGN330) are required (7.0 credits). Three more courses may be chosen from the proposed list of electives. The list of electives will be modified as new related courses become available.

Required Courses (7.0 credits)

- CBEN110 FUNDAMENTALS OF BIOLOGY I 4.0
- MEGN330 INTRODUCTION TO BIOMECHANICAL ENGINEERING 3.0

Biomechanical Engineering Elective Courses

- MEGN430 MUSCULOSKELETAL BIOMECHANICS 3.0
- MEGN435 MODELING AND SIMULATION OF HUMAN MOVEMENT 3.0
- MEGN536 COMPUTATIONAL BIOMECHANICS 3.0
- MEGN537 PROSTHETIC AND IMPLANT ENGINEERING 3.0
- MEGN553 INTRODUCTION TO COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS AND TRANSPORT PHENOMENA 3.0
- MEGNX98/X99 SPECIAL TOPICS 3.0
- MTGN472 BIOMATERIALS I 3.0
- MTGN570 BIOCOMPATIBILITY OF MATERIALS 3.0
- CBEN311 INTRODUCTION TO NEUROSCIENCE 3.0
- CBEN304 ANATOMY AND PHYSIOLOGY 3.0
- CBEN305 ANATOMY AND PHYSIOLOGY LAB 1.0
must complete a minimum of 12 credits from the following:

For an Area of Special Interest in Aerospace Engineering, the student developed in conjunction with industry, will help prepare Mines students below. Four of the courses currently exist in the mechanical engineering program directors)

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<th>Course Code</th>
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<tr>
<td>MEGN471</td>
<td>HEAT TRANSFER</td>
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The interdisciplinary Additive Manufacturing program will prepare undergraduates to meet the challenges of careers in additive manufacturing. Undergraduate students have the following degree options:

- Area of Special Interest (12 credits)
  - Requirements: AMFG401 and 9 credits of electives (see Table 1)
- Minor (18 credits)
  - Requirements: AMFG401 and 15 credits of electives (see Table 1)

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<th>Table 1: Undergraduate elective courses, listed by specialty area (AMFG531, AMFG 511 and FEGN 526 require approval by appropriate program directors)</th>
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Aerospace Engineering Minor

The Aerospace Engineering minor includes six required courses listed below. Four of the courses currently exist in the mechanical engineering curriculum, and two are new courses. Courses in this minor, some developed in conjunction with industry, will help prepare Mines students for a career in aerospace industries.

SPRS498 | INTRO TO SPACE EXPLORATION & RESOURCES | 3.0 |
MEGN414 | MECHANICS OF COMPOSITE MATERIALS | 3.0 |
MEGN451 | FLUID MECHANICS II - AERODYNAMICS | 3.0 |
MEGN451 | HEAT TRANSFER | 3.0 |
MEGN453 | AEROSPACE STRUCTURES | 3.0 |
MEGN454 | ORBITAL MECHANICS | 3.0 |
MEGN456 | SPACE OPERATIONS AND MISSION DESIGN | 3.0 |

Total Semester Hrs | 15.0 |

ASi in Aerospace Engineering

For an Area of Special Interest in Aerospace Engineering, the student must complete a minimum of 12 credits from the following:
MEGN300. INSTRUMENTATION & AUTOMATION. 3.0 Semester Hrs.
This course will explore instrumentation and automation of electro-
mechanical systems. Students will utilize LabView and electro-
mechanical instrumentation to solve advanced engineering problems.
Class activities and projects will highlight the utility of LabView for real-
time instrumentation and control. Prerequisite: MEGN200 (C- or better),
MEGN201 (C- or better).

MEGN301. MECHANICAL INTEGRATION & DESIGN. 3.0 Semester Hrs.
Students will utilize the engineering design process and knowledge in
systems level design to produce a mechanical product/process. Students
will reverse engineer a product/process to emphasize the steps in the
design process. Students will select a longer course project, which is
intended to reinforce engineering skills from other courses. The project
topics would parallel one of the four research disciplines in ME, and
students would be able to choose a topic pathway that emphasizes
opportunities for mechanical engineering graduates. Prerequisite:
MEGN200 (C- or better), MEGN201 (C- or better), MEGN300 (C- or
better).

MEGN315. DYNAMICS. 3.0 Semester Hrs.
This course will cover particle kinematics (including 2-D motion in x-
y coordinates, normal-tangential coordinates, & polar coordinates),
rigid body kinematics (Including relative velocities and accelerations),
rigid body kinetics (including the equation of motion, work and energy,
linear impulse-momentum, & angular momentum), and introduction to
vibrations. Prerequisite: CEEN241 (C- or better) and MATH225 (C- or
better). MATH225.

MEGN324. INTRODUCTION TO FINITE ELEMENT ANALYSIS. 3.0
Semester Hrs.
Equivalent with MEGN424,
This course aims to teach basic proficiency with Finite Element Analysis
(FEA), which is the most widely used computer aided engineering tool
in industry, academia, and government. Fundamentals of FEA theory
are introduced, but the majority of the course is spent learning practical
skills with commercial FEA software. Students will work interactively
with the instructor and with their peers to complete hands-on FEA examples
based primarily on problems in structural mechanics. Applications of FEA
for heat conduction, natural frequency analysis, and design optimization
are covered briefly. The course will conclude with a mini project on
which students use FEA skills for engineering analysis and design. The
importance of verification and validation (V&V) for critical evaluation of
FEA predictions is emphasized, and students will make frequent use of
statics and solid mechanics principles to corroborate their FEA results.
Prerequisite: MEGN212 (C- or better) or CEEN311 (C- or better).

MEGN330. INTRODUCTION TO BIOMECHANICAL ENGINEERING. 3.0
Semester Hrs.
The application of mechanical engineering principles and techniques
to the human body presents many unique challenges. The discipline of
Biomedical Engineering (more specifically, Biomechanical Engineering)
has evolved over the past 50 years to address these challenges.
Biomechanical Engineering includes such areas as biomechanics,
biomaterials, bioinstrumentation, medical imaging, and rehabilitation.
This course is intended to provide an introduction to, and overview of,
Biomechanical Engineering and to prepare the student for more
advanced Biomechanical coursework. At the end of the semester,
students should have a working knowledge of the special considerations
necessary to apply various mechanical engineering principles to the
human body. Prerequisite: MEGN212, CEEN311, PHGN200. Co-
requisite: MEGN315.

MEGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I,II,S) Supervised, full-time engineering related employment for a
continuous six-month period in which specific educational objectives
are achieved. Students must meet with the Department Head prior to
enrolling to clarify the educational objectives for their individual Co-
op program. Prerequisites: Second semester sophomore status and a
cumulative grade-point average of at least 2.00. 3 semester hours
credit will be granted once toward degree requirements. Credit earned in
MEGN340, Cooperative Education, may be used as free elective credit
hours if, in the judgment of the Department Head, the required term
paper adequately documents the fact that the work experience entailed
high-quality application of engineering principles and practice. Applying
the credits as free electives requires the student to submit a Declaration
of Intent to Request Approval to Apply Co-op Credit toward Graduation
Requirements form obtained from the Career Center to the Department
Head.

MEGN351. FLUID MECHANICS. 3.0 Semester Hrs.
This course will cover principles of fluid properties, fluid statics, control-
volume analysis, Bernoulli equation, differential analysis and Navier-
Stokes equations, dimensional analysis, internal flow, external flow,
open-channel flow, and turbomachinery. May not also receive credit
for CEEN310 or PEGN251. Prerequisite: CEEN241 (C- or better) or
MNGN317 (C- or better).

MEGN361. THERMODYNAMICS I. 3.0 Semester Hrs.
This course is a comprehensive treatment of thermodynamics from a
mechanical engineering point of view. Topics include: Thermodynamic
properties of substances inclusive of phase diagrams, equations of
state, internal energy, enthalpy, entropy, and ideal gases; principles
of conservation of mass and energy for steady-state and transient
analyses; First and Second Law of thermodynamics, heat engines, and
thermodynamic efficiencies; Application of fundamental principles with an
emphasis on refrigeration and power cycles. May not also receive credit
for CBEN210. Prerequisite: MATH213 (C- or better).

MEGN381. MANUFACTURING PROCESSES. 3.0 Semester Hrs.
Equivalent with MEGN380,
Manufacturing Processes is a survey course, that introduces a wide
variety of traditional and advanced manufacturing processes with
emphasis on process selection and hands-on experiences. Students are
expected to have basic knowledge in material science, basic machining
and GD&T before entering the class. Throughout the course students
analyze the relationships between material properties, process variables
and product functionality. Students design and evaluate processes for
identifying value while eliminating waste using learned skill-sets including
lean methodologies, six-sigma and statistical process control. Quality,
cost, standards and ethics related to manufacturing are discussed
throughout the semester. Prerequisite: MEGN201 with a grade of C- or
better and MTGN202. MEGN212.
MEGN398. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN408. INTRODUCTION TO SPACE EXPLORATION. 3.0 Semester Hrs.
Overview of extraterrestrial applications of science and engineering by covering all facets of human and robotic space exploration, including its history, current status, and future opportunities in the aerospace and planetary science fields. Subtopics include: the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), current research, missions, and projects, the international and commercial perspectives, and discussion of potential career opportunities. This seminar style class is taught by CSM faculty, engineers and scientists from space agencies and research organizations, aerospace industry experts, and visionaries and entrepreneurs of the private space commerce sector.

MEGN412. ADVANCED MECHANICS OF MATERIALS. 3.0 Semester Hrs.
This Advanced Mechanics of Materials course builds upon the learning outcomes of the pre-requisite Mechanics of Materials (Solid Mechanics) course to teach students the fundamentals of elastic deformations. Introduction to energy methods, strain and stress transformations, constitutive relations for isotropic and orthotropic materials, and to fracture mechanics is realized through theory development, application examples, and numerical solutions. Knowledge from this course will enable students to work on variety of engineering applications in Mechanical, Materials, Aerospace, Civil and related engineering fields. Prerequisite: MEGN212 (C- or better) or CEEN311 (C- or better).

MEGN414. MECHANICS OF COMPOSITE MATERIALS. 3.0 Semester Hrs.
Introductory course on the mechanics of fiber-reinforced composite materials. The focus of the course is on the determination of stress and strain in a fiber-reinforced composite material with an emphasis on analysis, design, failure by strength-based criteria, and fracture of composites. Anisotropic materials are discussed from a general perspective then the theory is specialized to the analysis of fiber-reinforced materials. Both thermal and hygroscopic sources of strain are introduced. Classical laminated plate theory is next developed, and design of laminated composite structures is introduced. The analysis of helically reinforced composite tubes concludes the course. Prerequisite: MEGN212 (C- or better).

MEGN416. ENGINEERING VIBRATION. 3.0 Semester Hrs.
This course introduces linear theory of mechanical vibrations as applied to single- and multi-degree-of-freedom systems. Specifically, students learn to analyze and measure free and forced vibrations of spring-mass-damper systems in response to different types of loading including harmonic, impulse, and general transient loading. Force balance and energy methods are introduced as means to create models of vibrating mechanical components. Ultimately, students learn to apply these theories to design vibration isolators and dampers for machines subject to translational and rotational vibrations, including machines with rotating unbalances and two or more vibrating masses. Prerequisite: MEGN315 (C- or better).

MEGN417. VEHICLE DYNAMICS & POWERTRAIN SYSTEMS. 3.0 Semester Hrs.
This course offers an introduction to automotive engineering with a focus on vehicle design, suspension, powertrain and aerodynamics. The course is designed to introduce students to both theoretical and practical concepts of vehicle design with applications in increasing fuel efficiency and vehicle performance. The study of automotive engineering is of increasing importance as new technologies emerge and advances continue to be made to existing designs to create the ultimate driving experience; while having minimal impact on the environment by reducing tailpipe gas emissions, noise pollution, and waste material during manufacturing of new vehicles. Prerequisite: MEGN315, MEGN324, MEGN361.

MEGN430. MUSCULOSKELETAL BIOMECHANICS. 3.0 Semester Hrs.
(II) This course is intended to provide mechanical engineering students with a second course in musculoskeletal biomechanics. At the end of the semester, students should have in-depth knowledge and understanding necessary to apply mechanical engineering principles such as statics, dynamics, and mechanics of materials to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. 3 hours lecture; 3 semester hours. Prerequisite: MEGN330 (C- or better).

MEGN433. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.
Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties, interactions with the environment, and computational optimization to construct detailed computer models and simulations of human movement. Prerequisite: MEGN315 with a grade C- or better, MEGN330 with grade of C- or better.

MEGN436. COMPUTATIONAL BIOMECHANICS. 3.0 Semester Hrs.
Computational Biomechanics provides an introduction to the application of computer simulation to solve fundamental problems in biomechanics and bioengineering. Musculoskeletal biomechanics, joint kinematics, medical image reconstruction, hard and soft tissue modeling, and medical device design are considered in the context of a semester-long project to develop and evaluate an artificial knee implant. Leading commercial software tools are introduced with hands-on exercises. An emphasis is placed on understanding the limitations of the computer model as a predictive tool and the need for rigorous verification and validation of all modeling tasks. Clinical application of biomechanical modeling tools is highlighted and impact on patient quality of life is discussed. Prerequisite: MEGN324 with a grade of C- or better, MEGN330 with a grade of C- or better.
MEGN441. INTRODUCTION TO ROBOTICS. 3.0 Semester Hrs.
(I, II) Overview and introduction to the science and engineering of intelligent mobile robotics and robotic manipulators. Covers guidance and force sensing, perception of the environment around a mobile vehicle, reasoning about the environment to identify obstacles and guidance path features and adaptively controlling and monitoring the vehicle health. A lesser emphasis is placed on robot manipulator kinematics, dynamics, and force and tactile sensing. Surveys manipulator and intelligent mobile robotics research and development. Introduces principles and concepts of guidance, position, and force sensing; vision data processing; basic path and trajectory planning algorithms; and force and position control. EENG307 is recommended to be completed before this course. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: EENG307, MEGN200 or CSCI261 or CSCI200, EENG281 or EENG282 or PHGN215.

MEGN451. FLUID MECHANICS II - AERODYNAMICS. 3.0 Semester Hrs.
Review of elementary fluid mechanics and engineering; Two-dimensional external flows, boundary layers, and flow separation; Gas dynamics and compressible flow: Isentropic flow, normal and oblique shocks, rocket propulsion, Prandtl-Meyer expansion fans; Application of computational fluid dynamics. Prerequisite: MEGN351 (C- or better).

MEGN453. AEROSPACE STRUCTURES. 3.0 Semester Hrs.
This course covers advanced mechanics of materials relevant to the analysis and design of aerospace structures. Focused topics include multiaxial stress states, nonsymmetric loading, composites, airframe loads, and shear flow emphasizing lightweight, often thin-walled structures common in aerospace applications. Other advanced topics will be introduced, time permitting. Prerequisite: MEGN212.

MEGN455. AEROSPACE SYSTEMS ENGINEERING. 3.0 Semester Hrs.
An introduction to aerospace systems engineering. This course is designed for students to explore both theoretical and practical systems engineering concepts and knowledge using examples drawn from the aerospace and defense industries. Starting with the systems engineering model, students will gain hands-on experience working with modern Model Based Systems Engineering (MBSE) software and develop systems engineering deliverables such as Concepts of Operations (ConOps) documents as part of a semester long project. Prerequisite: Best taken just before Senior Design or as a co-req with Senior Design I.

MEGN456. SPACE OPERATIONS AND MISSION DESIGN. 3.0 Semester Hrs.
Space Operations and Mission Design (SOMD) is a course for upper level undergraduate and graduate students at Mines who are interested in expanding their knowledge of astrodynamics, spacecraft and space mission design, project management, and systems engineering.
Upon leaving the course, students will have a head start on potential internships/careers in the aerospace industry armed with key vocabulary and terms, experience with industry relevant software and tools, and core skills and knowledge gained through practice addressing real-world problems in the space domain. Prerequisite: MEGN455.

MEGN458. INTRO TO SPACE EXPLORATION AND RESOURCES. 3.0 Semester Hrs.
Overview of human and robotic space exploration, including its history, current status, and future opportunities. Course topics cover the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), the aerospace industry, space commerce and law, and the international space activity. Emphasis is placed on the field of space resources, including their identification, extraction, and utilization to enable future space exploration and the new space economy.

MEGN461. THERMODYNAMICS II. 3.0 Semester Hrs.
This course extends the subject matter of Thermodynamics I (MEGN361) to include the study of exergy, ideal gas mixture properties, psychrometrics and humid air processes, chemical reactions, and the 1st, 2nd and 3rd Laws of Thermodynamics as applied to reacting systems. Chemical equilibrium of multi-component systems, and simultaneous chemical reactions of real combustion and reaction processes are studied. Concepts of the above are explored through the analysis of advanced thermodynamic systems. 3 hours lecture; 3 semester hours. Prerequisite: MEGN351 (C- or better), MEGN361 (C- or better).

MEGN466. INTRODUCTION TO INTERNAL COMBUSTION ENGINES. 3.0 Semester Hrs.
Introduction to Internal Combustion Engines (ICEs); with a specific focus on Compression Ignition (CI) and Spark Ignition (SI) reciprocating engines. This is an applied thermo science course designed to introduce students to the fundamentals of both 4-stroke and 2-stroke reciprocating engines ranging in size from model airplane engines to large cargo ship engines. Course is designed as a one-semester course for students without prior experience with IC engines, however, the course will also include advanced engine technologies designed to deliver more horsepower, utilize less fuel, and meet stringent emission regulations. Discussion of advancements in alternative fueled engines will be covered as well. This course also includes an engine laboratory designed to provide hands-on experience and provide further insight into the material covered in the lectures. Prerequisite: MEGN351 with a grade of C- or better, MEGN361 with a grade of C- or better. Co-requisite: MEGN471.

MEGN467. PRINCIPLES OF BUILDING SCIENCE. 3.0 Semester Hrs.
This course covers the fundamentals of building heating, ventilation, and air conditioning (HVAC) systems and the use of numerical heat and moisture transfer models to analyze or design different building envelope and HVAC systems. Prerequisite: MEGN351 with a grade of C- or better, MEGN361 with a grade of C- or better. Co-requisite: MEGN471.

MEGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN469,MTGN469. Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials-scientific perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisite: MEGN361 with a grade of C- or better or CBEN357 with a grade of C- or better.
MEGN471. HEAT TRANSFER. 3.0 Semester Hrs.
(I, II) Engineering approach to conduction, convection, and radiation, including steady-state conduction, non-steady-state conduction, internal heat generation conduction in one, two, and three dimensions, and combined conduction and convection. Free and forced convection including laminar and turbulent flow, internal and external flow. Radiation of black and grey surfaces, shape factors and electrical equivalence. Prerequisite: MEGN351 (C- or better), MEGN361 (C- or better), and MATH307. 3 hours lecture; 3 semester hours.

MEGN475. INTRODUCTION TO NUCLEAR ENGINEERING. 3.0 Semester Hrs.
An overview of major concepts and themes of nuclear engineering founded on the fundamental properties of the neutron, and emphasizing the nuclear physics bases of nuclear reactor design and its relationship to nuclear engineering problems. Major topics that introduce fundamental concepts in nuclear engineering include the physics and chemistry of radioactive decay, radiation detection, neutron physics, heat transfer in nuclear reactors, and health physics. Nuclear engineering topics relevant to current events are also introduced including nuclear weapons, nuclear proliferation, and nuclear medicine. Prerequisite: MATH225, PHGN200.

MEGN479. OPTIMIZATION MODELS IN MANUFACTURING. 3.0 Semester Hrs.
We address the mathematical formulation and solution of optimization models relevant in manufacturing operations. The types of deterministic optimization models examined include: (i) network models; (ii) linear programs; (iii) integer programs; and, (iv) nonlinear programs. Application areas include scheduling, blending, equipment replacement, logistics and transportation, among other topics. Students learn not only how to mathematically formulate the models, but also how to solve them with a state-of-the-art modeling language (Ampl) and appropriate solver (e.g., Cplex or Minos). Algorithms for each problem class will be briefly discussed.

MEGN481. MACHINE DESIGN. 3.0 Semester Hrs.
(I, II) In this course, students develop their knowledge of machine components and materials for the purpose of effective and efficient mechanical design. Emphasis is placed on developing analytical methods and tools that aid the design making process. The course focuses on determination of stress, strain, and deflection for static, static multiaxial, impact, dynamic, and dynamic multiaxial loading. Students will learn about fatigue failure in mechanical design and calculate how long mechanical components are expected to last. Specific machine components covered include shafts, springs, gears, fasteners, and bearings. 3 hours lecture; 3 semester hours. Prerequisite: MEGN315 (C- or better) or PHGN350 (C- or better), and MEGN324 (C- or better).

MEGN485. MANUFACTURING OPTIMIZATION WITH NETWORK MODELS. 3.0 Semester Hrs.
Equivalent with EBN456,
(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. 3 hours lecture; 3 semester hours. Prerequisite: MATH111.

MEGN486. LINEAR OPTIMIZATION. 3.0 Semester Hrs.
This course addresses the formulation of linear programming models, linear programs in two dimensions, standard form, the Simplex method, duality theory, complementary slackness conditions, sensitivity analysis, and multi-objective programming. Applications of linear programming models include, but are not limited to, the areas of manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. Prerequisite: MATH332 or EBN509.

MEGN487. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN587,
This course addresses both unconstrained and constrained nonlinear model formulation and corresponding algorithms (e.g., Gradient Search and Newton's Method, and Lagrange Multiplier Methods and Reduced Gradient Algorithms, respectively). Applications of state-of-the-art hardware and software will emphasize solving real-world engineering problems in areas such as manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with an algorithm such as MINOS) these optimization problems is introduced. Offered every other year. Prerequisite: MATH111.

MEGN488. INTEGER OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN588,
(I) This course addresses the formulation of integer programming models, the branch-and-bound algorithm, total unimodularity and the ease with which these models are solved, and then suggest methods to increase tractability, including cuts, strong formulations, and decomposition techniques, e.g., Lagrangian relaxation, Benders decomposition. Applications include manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. 3 hours lecture; 3 semester hours. Prerequisite: MATH111.

MEGN498. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Note that MEGN499 does not count as an MEGN Technical Elective, though the course does count as a Free Elective. Prerequisite: Independent Study form must be completed and submitted to the Registrar.

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