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Colorado School of Mines Bulletin

2015-2016

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

2015-2016

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

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Golden, CO 80401

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Toll Free: 800-446-9488
http://gradschool.mines.edu/GS-Graduate-Office-Staff

Academic Calendar

Fall Semester 2015

Description	Date(s)	Day(s) of Week
Confirmation Deadline	Aug. 24	Monday
Faculty Conference	Aug. 24	Monday
Classes Start (1)	Aug. 25	Tuesday
Graduate Student Registration Deadline - Late Fee Applied After this Date	Aug. 28	Friday
Labor Day - Classes in Session	Sep. 7	Monday
Census Day	Sep. 9	Wednesday
Fall Break (not always Columbus Day)	Oct. 19 & 20	Monday & Tuesday
Midterm Grades Due	Oct. 19	Monday
Last Withdrawal - Continuing Students (12 wks)	Nov. 13	Friday
Priority Registration for Spring Term	Nov. 16-20	Monday - Friday
Non-Class Day prior to Thanksgiving Break	Nov. 25	Wednesday
Thanksgiving Break - Campus Closed	Nov. 26-27	Thursday & Friday
Last Withdrawal - New Freshmen & Transfers	Dec. 4	Monday
Classes End	Dec. 10	Thursday
Dead Week - no exams	Dec. 7-11	Monday - Friday
Dead Day - no academic activities	Dec. 11	Friday
Final Exams	Dec. 12, 14-17	Saturday, Monday - Thursday
Semester Ends	Dec. 18	Friday
Commencement	Dec. 18	Friday
Final Grades Due	Dec. 21	Monday
Winter Break	Dec. 21 - Jan 12	

Spring Semester 2016

Description	Date(s)	Day(s) of Week
Confirmation Deadline	Jan. 12	Tuesday
Classes Start (1)	Jan. 13	Wednesday
Graduate Student Registration Deadline - Late Fee Applied After this Date	Jan. 15	Friday
Census Day	Jan. 28	Thursday
Non-Class Day - President's Day	Feb. 15	Monday
Midterm Grades Due	Mar. 7	Monday
Spring Break - 9th full week of Spring Term	Mar. 14-18	Saturday - Sunday
Last Withdrawal - Continuing & Grad (13 weeks)	April 7	Thursday
E-Days	Mar. 31 - April 2	Thursday - Saturday

Description	Date(s)	Day(s) of Week
Priority Registration Summer/Fall	April 11-15	Monday - Friday
Last Withdrawal - New Freshmen & Transfers	April 29	Friday
Classes End	May 5	Thursday
Dead Week - No Exams	May 2-6	Monday - Friday
Dead Day - No Academic Activities	May 6	Friday
Final Exams	May 7, 9-12	Saturday, Monday - Thursday
Semester Ends	May 13	Friday
Commencement	May 13	Friday
Final Grades Due	May 16	Monday

Summer Sessions 2016

Description	Date(s)	Day(s) of Week
Summer I Starts (6-week session) (1)	May 16	Monday
Summer I Census	May 20	Friday
Memorial Day - No Classes, Campus Closed	May 30	Monday
Summer I Last Withdrawal - All Students	June 10	Friday
Summer I Ends	June 24	Friday
Summer I Grades Due	June 27	Monday
Summer II Starts (6-week session) (1)	June 27	Monday
Summer II Census	July 1	Friday
Independence Day - No Classes, Campus Closed	July 4	Friday
Summer II Last Withdrawal - All Students	July 22	Friday
Summer II Ends (2)	Aug. 5	Friday
Summer II Grades Due	Aug. 8	Monday
Summer Grades Available on Transcript	Aug. 24	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 Friday, August 19th.

Facilities and Academic Support

Arthur Lakes Library

Arthur Lakes Library is a regional information center for engineering, energy, minerals, materials, and associated engineering and science fields. The Library supports university education and research programs and is committed to meeting the information needs of the Mines community and all library users.

The Library has over 140,000 visitors a year and is a campus center for learning, study and research. Facilities include meeting space, a campus computer lab, and individual and group study space. We host many cultural events during the year, including concerts and art shows.

The librarians provide personalized help and instruction, and assist with research. The Library's collections include more than 500,000 books; thousands of print and electronic journals; hundreds of databases; one of the largest map collections in the West; an archive on Colorado School of Mines and western mining history; and several special collections. The Library is a selective U.S. and Colorado state depository with over 600,000 government publications.

The Library Catalog provides access to Library collections and your user account. Our databases allow users to find publications for classroom assignments, research or personal interest. Students and faculty can use most of the Library's electronic databases and publications from any computer on the campus network, including those in networked Mines residential facilities. Dial-up and Internet access are available out of network.

Arthur Lakes Library is a member of the Colorado Alliance. Students and faculty can use their library cards at other Alliance libraries, or can order materials directly using Prospector, our regional catalog. Materials can also be requested from anywhere in the world through interlibrary loan.

Cecil H. and Ida Green Graduate and Professional Center

Completed in 1971, the Cecil H. and Ida Green Graduate and Professional Center is named in honor of Dr. and Mrs. Green, major contributors to the funding of the building. Dr. Green was a co-founder and Vice President for Texas Instruments.

Bunker Auditorium can accommodate 1,100 patrons in theater style seats. Minimal stage facilities, an orchestra pit with an orchestra lift, digital pipe organ and 9' concert grand piano. Bunker Auditorium is home to weekly campus movie nights.

Friedhoff Hall 1 seats up to 320 persons for banquets, or can be configured for lectures, receptions and dances. Friedhoff 1 has hardwood floors, a built in stage, grand staircase entrance and 26 foot high ceilings. Friedhoff 1 has three LCD projectors and a concert grade sound system making it one of the premier lecture venues on campus. Theatre Style seating can be accommodated in Friedhoff Hall 1 up to 400 persons.

Friedhoff Hall 2 seats up to 288 persons for banquets. Friedhoff 2 has carpeted floors, indirect architectural lighting and 12 foot high ceilings.

Friedhoff Hall 3 accommodates 48 persons. Friedhoff 3 has carpeted flooring and can lighting also with 12 foot high ceiling.

Green Center banquet furnishings consist of 5-foot round tables with 8 chairs per table.

Petroleum Hall seats 122 persons and is not used for academic classes. Petroleum Hall is home to Special Programs and Continuing Education events.

Metals Hall is our largest lecture hall. Seating is mixed with 45 cushioned office chairs and 270 fixed folding-tablet armchairs with a total capacity of 315. Metals Hall has limited availability for events as it is used for academic classes.

For more information visit www.greencenter.mines.edu.

Computing, Communications, & Information Technologies (CCIT)

Campus Computing, Communications, & Information Technologies (CCIT) provides computing and networking services to meet the instructional, research, administrative, and networking infrastructure needs of the campus. CCIT manages and operates campus networks along with central academic and administrative computing systems, telecommunication systems, a high performance computing cluster for the energy sciences (see http://geco.mines.edu), and computer classrooms and workrooms in several locations on campus. CCIT's customer services and support group also provides direct support for most electronic classrooms, departmental laboratories and desktops throughout the campus.

Central computing accounts and services are available to registered students and current faculty and staff members. Information about hours, services, and the activation of new accounts is available on the web site at http://ccit.mines.edu/, directly from the Help Desk in the Computer Commons (in CTLM 156), or by calling (303) 273-3431.

Workrooms in several locations on campus contain networked PCs and workstations. Printers, scanners, digitizers, and other specialized resources are available for use in some of the locations.

In addition to central server and facilities operations, services supported for the campus community include email, wired and wireless network operation and support, access to the commodity Internet, Internet 2, and National Lambda Rail, network security, volume and site licensing of software, online training modules, videoconferencing, student registration, billing, and other administrative applications, campus web sites and central systems administration and support. CCIT also manages and supports the central learning management system (Blackboard), printing, short-term equipment loan, and room scheduling for some general computer teaching classrooms.

All major campus buildings are connected to the computing network operated by CCIT and most areas of the campus are covered by the wireless network. All residence halls and the Mines Park housing complex are wired for network access and some fraternity and sorority houses are also directly connected to the network.

All users of Colorado School of Mines computing and networking resources are expected to comply with all policies related to the use of these resources. Policies are available via the web pages at http://ccit.mines.edu.

Copy Center

Located on the first floor of Guggenheim Hall, the Copy Center offers online binding, printed tabs, transparencies and halftones. Printing can be done on 8 ½"x 11", 11"x14" and 11"x17" paper sizes from odd-sized originals. Some of the other services offered are GBC and Velo Binding, folding, sorting and machine collating, reduction and enlargement, two sided copying, and color copying. We have a variety of paper colors, special resume paper and CSM watermark for thesis copying. These services are available to students, faculty, and staff. The Copy Center campus extension is 3202.

CSM Alumni Association

The Colorado School of Mines Alumni Association (CSMAA), established in 1895, serves the Colorado School of Mines and more than 23,000 proud members of the powerful and successful alumni community. While all alumni are included in the reach of the CSMAA, it is a membership-based, independent organization reliant upon membership funds for much of its budget. Other sources of funding include the School, Foundation, merchandise sales and revenue-sharing partnerships. For example, CSMAA administers the Colorado School of Mines license plate program for cars registered in Colorado.

General services and programs include:

- Mines magazine, a quarterly publication covering campus and alumni news;
- An online directory of all Mines alumni for networking purposes;
- Online job listings for alumni two years out of school;
- Access to the alumni network on LinkedIn;*
- Section activities that provide social and networking connections to the campus and Mines alumni around the world;
- Alumni gatherings (meetings, reunions, golf tournaments, educational programs and other special events) on and off campus;
- Alumni recognition awards;
- On-campus CSM library privileges for Colorado residents;

Benefits for current Colorado School of Mines students include:

- Legacy Grants for children or grandchildren of alumni when parent or grandparent has been a consistent member of CSMAA for previous five years;
- The Student Financial Assistance Program;
- Celebration of Alumni banquet for graduating students;
- The CSMAA Mentorship program, pairing students with alumni for professional development;*
- Invitations to social and networking events, i.e. Dinner and Dialogue, Leadership Development events, Holiday Party, sporting events
- Access to the alumni network on LinkedIn;*
- Access to the CSMAA social networking website, www.minesonline.net (http://www.minesonline.net);
- Early notice, information and reminders about alumni-based scholarships;
- Exclusive opportunities to enter drawings for a CSMAA book scholarship;*
- CSM Bookstore discounts (excluding textbooks and Apple products);*
- Renter's insurance discount from Liberty Mutual;

- "Blaster Pack" – Mines marbles, an "M"-ulator t-shirt, membership card and more;*

Students can join the CSMAA at the student membership ("M"-ulator) level for exclusive benefits marked with an asterisk. For further information:
call 303-273-3295,
Fax 303-273-3583,
email csmaa@mines.edu (//csmaa@mines.edu),

or write:
Mines Alumni Association,
Coolbaugh House,
P.O. Box 1410,
Golden, CO 80402-1410.

Environmental Health and Safety

The Environmental Health and Safety (EHS) Department is located in Chauvenet Hall room 194. The Department provides a variety of services to students, staff and faculty members. Functions of the Department include: hazardous waste collection and disposal; chemical procurement and distribution; chemical spill response; assessment of air and water quality; fire safety; laboratory safety; industrial hygiene; radiation safety; biosafety; and recycling. Staff is available to consult on issues such as chemical exposure control, hazard identification, safety systems design, personal protective equipment, or regulatory compliance. Stop by our office or call 303 273-3316. The EHS telephone is monitored nights and weekends to respond to spills and environmental emergencies.

LAIS Writing Center

Located on the third floor of Stratton Hall (phone: 303-273-3085), the LAIS Writing Center is a teaching facility providing all CSM students, faculty, and staff with an opportunity to enhance their writing abilities. The LAIS Writing Center faculty are experienced technical and professional writing instructors who are prepared to assist writers with everything from course assignments to theses and dissertations, to scholarship and job applications. This service is free to CSM students, faculty, and staff and entails one-to-one tutoring and online resources (at http://www.mines.edu/acade- mic/lais/wc/).

Off-Campus Study

A student must enroll in an official CSM 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 CSM or led by a CSM 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.

Office of International Programs

The Office of International Programs (OIP) fosters and facilitates international education, research and outreach at CSM. OIP is administered by the Office of Academic Affairs.

OIP is located in 1706 Illinois Street. For more specific information about study abroad and other international programs, contact OIP at 384-2121 or visit the OIP web page (http://OIP.mines.edu).

The office works with the departments and divisions of the School to:

1. help develop and facilitate study abroad opportunities for CSM undergraduate and graduate students and serve as an informational and advising resource for them;
2. assist in attracting new international students to CSM;
3. serve as an information resource for faculty and scholars of the CSM community, promoting faculty exchanges and the pursuit of collaborative international research activities;
4. foster international outreach and technology transfer programs;
5. facilitate arrangements for official international visitors to CSM; and
6. in general, help promote the internationalization of CSM's curricular programs and activities.

Graduate students may apply for participation in dual degree programs offered by CSM and its partners. Generally these programs require the preparation and defense of one jointly supervised thesis project and the completion of degree requirements at each participating university (http:/OIP.mines.edu/studentabroad/schol.html).

Office of Research

Mines is a global leader in research and the advancement of technology. Led by our world-class faculty, the research conducted at Mines enhances the educational experience of our graduates. Students have the opportunity to actively participate in research at every level of their education.

Our research spans many highly relevant areas with a specific focus on **energy and environmental stewardship**. Our first-rate facilities and partnerships with industry, national laboratories, other universities, funding agencies and international institutions enable us to maintain our cutting edge research and have a significant impact on real world problems. Research is a cooperative effort in the Mines community.

For more information about the Office of Research please contact: Lisa Kinzel, Executive Assistant for Research, lkinzel@mines.edu or (303) 384-2470

Office of Technology Transfer

TThe purpose of the Office of Technology Transfer (OTT) is to reward innovation and entrepreneurial activity by students, faculty and staff, recognize the value, preserve ownership of CSM's intellectual property, and contribute to local and national the economic growth. OTT reports directly to the Vice President of Research and Technology Transfer and works closely with the school's offices of Legal Services and Research Administration to coordinate activities. With support from its external Advisory Board, OTT strives to:

1. Initiate and stimulate entrepreneurship and development of mechanisms for effective investment of CSM's intellectual capital;
2. Secure CSM's intellectual properties generated by faculty, students, and staff;
3. Contribute to the economic growth of the community, state, and nation through facilitating technology transfer to the commercial sector;
4. Retain and motivate faculty by rewarding entrepreneurship;

5. Utilize OTT opportunities to advance high-quality faculty and students;
6. Provide a return on investment on CSM inventions which is used to expand the school's research and education missions.

Public Relations

For information about the school's publications guidelines, including the use of Mines logos, and for media-related requests, contact:
Karen Gilbert, Public Relations Director,
303-273-3541 or
kgilbert@mines.edu (//kgilbert@mines.edu).

Registrar

The Office of the Registrar supports the academic mission of the Colorado School of Mines by providing service to our current and former students, faculty, staff, and administration. These services include maintaining and protecting the integrity and security of the official academic record, registration, degree verification, scheduling and reporting. Our office routinely reviews policy, makes recommendations for change, and coordinates the implementation of approved policy revisions.

The Office of the Registrar seeks to fulfill this mission through a commitment to high quality service provided in a professional, efficient and courteous manner. Our specific services include but are not limited to:

- Enrollment and degree verifications
- Transcripts
- Degree auditing and diplomas (undergraduate)
- Transfer credit entry and verification
- Veteran's Administration Certifying Official services
- Registration setup and execution
- Course and room scheduling
- Academic and enrollment reporting
- Residency for current students
- Grade collection, reporting and changes

Management of the Registrar's Office adheres to the guidelines on professional practices and ethical standards developed by the American Association of Collegiate Registrars and Admissions Officers (AACRAO). Our office also complies with the Family Educational Rights and Privacy Act of 1974 (FERPA), Colorado Department of Higher Education rules and policies, and the Colorado School of Mines policies on confidentiality and directory information.

The Registrar's Office is located in the Student Center, Room 31.

Hours of operation are:
Monday/Tuesday/Thursday/Friday, 9am-5pm;
Wednesday 10am-5pm.

The office phone number is (303) 273-3200.
The fax number is (303) 384-2253.

Lara Medley represents Colorado School of Mines as the Registrar. She is normally available on a walk-in basis (when not in meetings) if a student or other client has an issue that needs special attention. Appointments are also welcomed.

Research Administration

The Office of Research Administration (ORA), under the Vice President for Finance and Administration, provides administrative support in proposal preparation and contract and grant administration, which includes negotiation, account set-up, and close out of expired agreements. Information on any of these areas of research and specific forms can be accessed on our web site at www.is.mines.edu/ora.

Office of Strategic Enterprises

The mission of the Office of Strategic Enterprises (OSE) is to bring Mines' educational and intellectual resources to the world and enable professionals, corporate entities, and universities from around the globe to interact with Mines. The goal is a distinctive "anywhere, anytime" approach to learning in a fast-paced, changing world. Initiatives include executive and corporate training, non-degree courses, and summer intensives. Professionals needing continuing education can find short-term and part-time offerings, targeted training, off-campus programs and certificate courses. OSE also reaches out to prospective universities on different continents to initiate partnerships that could benefit from Mines' academic capabilities in resource or energy development. Advancing Mines' global mission in other countries, OSE increases opportunities for international researchers to study at Mines, and for Mines researchers to work at international facilities. The Office of Special Programs and Continuing Education (SPACE) reports to OSE and administers most of the programmatic offerings. For further information about OSE, visit inside.mines.edu/Educational_Outreach.

Special Programs and Continuing Education (SPACE)

The SPACE Office administers short courses, special programs, and professional outreach programs to practicing engineers and other working professionals. Short courses, offered both on the CSM campus and throughout the US, provide concentrated instruction in specialized areas and are taught by faculty members, adjuncts, and other experienced professionals. The Office offers a broad array of programming for K-12 teachers and students through its Teacher Enhancement Program, and the Denver Earth Science Project. The Office also coordinates educational programs for international corporations and governments through the International Institute for Professional Advancement and hosts the educational portion of the Mine Safety and Health Training Program. A separate bulletin lists the educational programs offered by: the SPACE Office, CSM,
1600 Jackson Street, Suite 160A
Golden, CO 80401.
Phone: 303-279-5563;
FAX 303-277-8683;
email space@mines.edu (//space@mines.edu);
website www.mines.edu/Educational_Outreach.

Telecommunications

The Telecommunications Office is located in the CTLM building 2nd floor east end room 256 and provides telephone services to the campus. The office is open 8:00am to 4:00pm Monday through Friday, and can be reached by calling (303) 273-3355 or via the web at http://inside.mines.edu/Telecommunications.

Courtesy phones are provided on each floor of the traditional residence halls and Weaver Towers as well as school owned fraternities and sororities. In-room phones are available to students living in Mines Park for $18.50 per month. Students wishing to take advantage of in-room phones in Mines Park should contact the Telecommunications Office to arrange for service. Telephone sets are not provided by the Telecommunications Office.

Students may make long distance calls from any CSM provided phone by using a third party calling card. Access to third party carriers is available through toll-free (800, 888, 877, 866 and 855) numbers provided by the third party carrier along with the appropriate instructions.

Women in Science, Engineering and Mathematics (WISEM) Program

The mission of WISEM is to enhance opportunities for women in science and engineering careers, to increase retention of women at CSM, and to promote equity and diversity in higher education. The office sponsors programs and services for the CSM community regarding gender and equity issues. For further information, contact:
Debra K. Lasich, Executive Director, WISEM Program,
Colorado School of Mines,
1710 Illinois Street,
Golden, CO 80401-1869.
Phone (303) 273-3097;
email dlasich@mines.edu (//dlasich@mines.edu);
website http://wisem.mines.edu/.

Librarian

Joanne V. Lerud-Heck, Library Director

Lisa G. Dunn

Laura A. Guy

Associate Librarian

Lisa S. Nickum

Christopher Thiry

Heather L. Whitehead

Assistant Librarian

Patricia E. Andersen

Christine Baker

Pamela M. Blome

Lia Vella

Research Librarian

Julie Carmen

CIO

Derek Wilson

CISO

Phil Romig, III, Director, Computing & Networking Infrastructure

Director

Gina Boice, Customer Services & Support

Tim Kaiser, High Performance and Research Computing

David Lee, Enterprise Systems

George Funkey, Policy, Planning, & Integration Services

Registrar

Lara Medley

Associate Registrar

Dahl Grayckowski, for Systems

Diana Anglin, for Operations

Assistant Registrar

Tabatha Grayckowski, for Graduation

Specialist

Margaret Kenney, Reporting

Nolan Oltjenbruns, Registration

Judy Westley, Records

Senior Vice President

Nigel Middleton

General Information

2015-2016

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 masters 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.

Masters Programs

The Colorado School of Mines offers a wide variety of Masters-level degree programs that include thesis and non-thesis Master of Science programs, Master of Engineering programs, Professional Master's programs and a Master of International Political Economy of Resources. While the objectives and outcomes provided below document expectations of all Masters-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. Masters graduates will contribute to the advancement of their chosen fields through adopting, applying and evaluating state-of-the-art practices.
2. Masters graduates will be viewed within their organizations as technologically advanced and abreast of the latest scholarship.
3. Masters graduates will exhibit the highest standards of integrity in applying scholarship.
4. Masters 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:

The Employment-related EEO and discrimination contact is:
Mike Dougherty, Associate Vice President for Human Resources
Guggenheim Hall, Room 110
Golden, Colorado 80401
(Telephone: 303.273.3250)

The ADA Coordinator and the Section 504 Coordinator for employment is:
Ann Hix, Benefits Manager, Human Resources
Guggenheim Hall, Room 110
Golden, Colorado 80401
(Telephone: 303.273.3250)

The ADA Coordinator and the Section 504 Coordinator for students and academic educational programs is:
Kristen Wieger, Coordinator of Student Disability Services
Student Wellness Center, 1770 Elm Street
Golden, Colorado 80401

(Telephone: 303.273.3377)

The Title IX Coordinator is:
Karin Ranta-Curran, Assistant Director of HR for EEO and Equity
Guggenheim Hall, Room 110
Golden, CO 80401
(Telephone: 303.384.2558)
(E-Mail: 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

2015-2016

http://gradschool.mines.edu

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 at right.

In addition to masters 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

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.
Applied Mathematics and Statistics		x		x
Applied Physics		x		x
Chemical Engineering		x		x
Chemistry		x		
Applied Chemistry				x
Civil & Environmental Engineering		x		x
Computer Sciences		x		x
Electrical Engineering		x		x
Engineering Systems		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
International Political Economy & Resources		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
Nuclear Engineering		x	x	x
Operations Research with Engineering**				x
Petroleum Engineering		x	x	x
Petroleum Reservoir Systems	x			
Underground Construction and Tunneling		x		x

*   Master of International Political Economy of Resources

**   Interdisciplinary degree with specialty in Operations Research with Engineering

Admission to the Graduate School

2015-2016

Admission Requirements

The Graduate School of Colorado School of Mines is open to graduates from four-year programs at recognized colleges or universities. 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 department outlined later in this section of the Bulletin.

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 Bulletin 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:

The Graduate Office, CSM
Golden, CO 80401-0028
Phone: 303-273-3247

A person admitted as a nondegree 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 student may be transferred into the regular degree program if the student's graduate committee and department head approve. Transfer credits must not have been used as credit toward a Bachelor's degree.

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:

The Office of International Programs, CSM
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 foreign exchange student and not used toward a bachelor's degree may be transferred into the regular degree program if 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 Bulletin.

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.

Admission Procedure

Applying for Admission

Both US resident and international students may apply electronically for admission. Our Web address is: http://www.mines.edu/gradschoolapp/onlineapp.html

To apply follow the procedure outlined below.

1. Application: Go to the online application form at http://www.mines.edu/gradschoolapp/onlineapp.html. 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
   June 1 - International student deadline
   July 1 - Domestic student deadline
   for Spring Admission*
   September 1
   *   Some programs have different application deadlines. Please refer to http://www.mines.edu/Deadlines_GS for current deadline information for specific programs.

   Students wishing to submit applications beyond the final deadline should contact the Graduate Office.

2. Transcripts: The Graduate Office 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 Graduate Office.

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: http://www.mines.edu/Intl_GS. English proficiency may be proven by achieving one of the following:
   a. A TOEFL (Test of English as a Foreign Language) minimum score of 550 on the paper-based test or a score of 79 on the internet Based TOEFL (iBT).
   b. At 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.

Financial Assistance

To apply for Mines financial assistance, check the box in the Financial Information section of the online graduate application or complete the Financial Assistance section on the paper application.

Application Review Process

When application materials are received by the Graduate School, they are processed and sent 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 to the Dean of the Graduate School, who 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 CSM. 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

2015-2016

Housing

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, cable television, wired and wireless internet connections, and an optional campus phone line for an additional fee. 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.

For all Housing & Dining rates, go to Tuition, Fees, Financial Assistance, Housing (bulletin.mines.edu/undergraduate/tuitionfeesfinancialassistancehousing)

Facilities

Student Center

The Ben H. Parker Student Center contains the offices for the Vice President of Student Life and Dean of Students, Associate Dean of Students, Student Activities , Student Government (USG and GSG), Financial Aid, Cashier, Bursar, Career Center, Registrar, Conference Services, and student organizations. The Student Center also contains The Period 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 Benefits Plan, the Counseling Center, the Dental Clinic and Student Disability Services. The wellness center is open from 8:00 am to 5:00 pm, Monday through Friday, during the fall and spring semesters.

Coulter Student Health Center: Services are provided to all students who have paid the student health center fee. The Coulter Student Health Center (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 Monday through Friday 8:00 am to 12:00 pm and 1:00 pm to 4:45 pm and 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 CSM student). The Health Center offers primary health and dental care. For X-rays, specialists or hospital care, students are referred to approprishy;ate providers in the community. More information is available at http://healthcenter.mines.edu.

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 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. Dental care is on a fee-for-service basis, and students enrolled in the CSM Student Health Benefits Plan pay lower rates for dental care. The Dental Clinic takes cash or checks, no credit/debit cards

Fees: Students are charged a mandatory Health Services fee each semester, which allows them access to services at the Health Center. Spouses of enrolled CSM students can choose to pay the health center fee and are eligible for services. Dental services are not availshy;able to spouses.

Immunization Requirement: The State of Colorado requires that all students enrolled have proof of two MMR's (measles, mumps and rubella). A blood test showing immunity to all three diseases is acceptable. History of disease is not acceptable.

Student Health Benefits Plan: The SHBP 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 Benefits Plan and may waive coverage if they have comparable coverage under a personal or employer plan. International students must purchase the SHBP, unless they meet specific requirements. Information about the CSM Student Health Benefits 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 CSM Student Health Benefits Plan is done online for U.S. Citizens and Permanent Residents. International students must compete a paper enrollment/waiver form. The deadline is Census Day.

Counseling Center: Located on the second floor of the W. Lloyd Wright Student Wellness Center, phone 303-273-3377. Services are available for students who have paid the Student Services fee. Individual personal, academic, and career counseling is offered on a short-term basis to all enrolled CSM students. In cases where a student requires longer-term counseling, referrals are made to providers in the local community. The Counseling Center also provides education and assessment on

alcohol and other drug use. More information is available at http:// counseling.mines.edu/.

Student Disability 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 an 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 http:// disabilities.mines.edu/.

Services

Academic Advising & Support Services

Center for Academic Services and Advising (CASA)

Academic Advising: All students entering CSM are assigned an Academic Advising Coordinator. This assignment is made by last name. This Coordinator serves as the student's academic advisor until they formally declare their major or intended degree. This declaration occurs in their sophomore year. Incoming students have only noted an interest and are not declared.

The Coordinators will host individual, walk-in, and group advising sessions throughout the semester. Every student is required to meet with their Coordinator at least once per semester. The Coordinator will administer a PIN for course registration, each semester. Students unsure of their academic path (which major to choose) should work with their Coordinator to explore all different options.

CASA also hosts Peer 2 Peer advising. Students may walk-in and speak with a fellow student on various issues pertaining to course, such as course registration).

CSM101: The First-Year Symposium, , is a required, credit-bearing class. CSM101 aims to facilitate the transition from high school to college; create community among peers and upper-class students; assess and monitor academic progress; and provide referrals to appropriate campus resources. CSM101 is taught by 38 professional staff members (including faculty) and 76 Peer Mentor students.

Tutoring Services: CASA offers weekly tutoring services for all core-curriculum courses. Our services run Sunday through Thursday and are hosted in CASA, the Student Center, and the Library. Students may also request to meet with a private tutor at a time, location, and date of their mutual choosing. All tutoring services are free to students.

Academic Support Services: Routinely, CASA offers great support workshops and events. CASA hosts pre-finals workshops as well as mid-term exam prep session. As well, students can work with our staff to develop the skills and technique of studying well in college – such as test-prep and cognitive learning development. CASA hosts late-night programs in the residence halls and Greek houses.

Core Supplemental Instruction (CSI): First-Year students are encouraged to attend our CSI workshops. These workshops run concurrent to many of the first-year classes (Calc, Chem, Physics, etc.) and reiterate/strengthen material taught in class. They are offered in the evening and are free to all students.

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

Website: CASA maintains an extensive website with resources, helpful tips, and guides. Check out CASA at http://casa.mines.edu.

Motor Vehicles Parking

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

Public Safety

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

The department is responsible for providing services such as:

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

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

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. All Colorado School of Mines graduates will be able to acquire the necessary job search and professional development skills to enable them to successfully take personal responsibility for the management of their own careers.
  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 http://careers.mines.edu;
- Individual resume and cover letter critiques;
- Individual job search advice;
- Practice video-taped interviews;
- Job Search Workshops - successful company research, interviewing, resumes, business etiquette, networking skills;
- Salary and overall outcomes data;
- Information on applying to grad school;
- Career resource library.

Job Resources and Events

- Career Day (Fall and Spring);
- Online and in-person job search assistance for internships, CO-OPs, and full-time entry-level job postings;
- Virtual Career Fairs and special recruiting events;
- On-campus interviewing - industry and government representatives visit the campus to interview students and explain employment opportunities;
- General employment board;
- Company research resource;
- Cooperative Education Program - available to students who have completed three semesters at Mines (two for transfer students). It is an academic program which offers 3 semester hours of credit in the major for engineering work experience, awarded on the basis of a term paper written following the CO-OP term. The type of credit awarded depends on the decision of the department, but in most cases is additive credit. CO-OP terms usually extend from May to December, or from January to August, and usually take a student off campus full time. Students must apply for CO-OP before beginning the job (a no credit, no fee class), and must write learning objectives and sign formal contracts with their company's representative to ensure the educational component of the work experience.

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 allows students to ride RTD buses and light rail free of charge (or for a reduced fee for airport bus service). 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 CSM Library, to access certain electronic doors, and may be required to attend various CSM 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 and Governance website at

http://inside.mines.edu/POGO-Policies-Governance. 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 Associate Dean of Students located in the Student Center, Suite 218.

Student Publications

Two student publications are published at CSM by the Associated Students of CSM. Opportunities abound for students wishing to participate on the staffs. A Board of Student 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

Student Activities Office

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

Student Government

Associated Students of CSM (ASCSM) is sanctioned by the Board of Trustees of the School. The purpose of ASCSM is, in part, to advance the interest and promote the welfare of CSM and all of the students and to foster and maintain harmony among those connected with or interested in the School, including students, alumni, faculty, trustees and friends.

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 Graduate Student Association was formed in 1991 and is recognized by CSM through the student government as the representative voice of the graduate student body. GSA's primary goal is to improve the quality of graduate education and offer academic support for graduate students.

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 (http://inside.mines.edu/RSL-Residence-Hall-Association).

Student Organizations

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

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

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

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

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

Professional Societies - Professional Societies are generally student chapters of the national professional societies. As a student chapter, the professional societies offer a chance for additional professional development outside the classroom through guest speakers, trips, and interactive discussions about the current activities in the profession. Additionally, many of the organizations offer internship, fellowship and scholarship opportunities.

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

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

Registration and Tuition Classification

2015-2016

General Registration Requirements

The normal full 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.

Except for students meeting any of the following conditions, students may register at less than the required full-time registration.

- 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 bulletin to see if this applies to a particular program.

Students for whom any one of these conditions apply must register at the appropriate full-time credit hour requirement. 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 students who have completed their credit-hour requirements and are working full time on their thesis.

To remain active in their degree program, students must register continuously each fall and spring semester. If not required to register full-time, part-time students may register for any number of credit hours less than the full-time credit hour load.

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 entering during the fall semester will be expected to pay full student fees for any courses taken in the summer sessions prior to the fall term of entry.

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. 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.

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, completion of 36 hours of eligible course, research and transfer credits combined
2. For Ph.D. students, completion of 72 hours of eligible course, research, and transfer credits combined
3. For all students, an approved 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. Candidates may not count more than 12 credit hours per semester in determining eligibility for reduced, full-time registration.

Students who are eligible for reduced, full-time 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. However, international students need only register for 6 credit hours during their first year, if they are required to take special language instruction or are accepted in Provisional Status. In the event a thesis-based student has completed his or her required course work and research credits and is eligible for reduced, full-time 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.

Internships and Academic-Year Registration Requirements

Thesis-based graduate students may participate in corporate-sponsored internship opportunities during the academic year. The intent of graduate internships is to allow students to continue to advance toward degree while pursuing research activities off campus, that are of interest to both the student and a corporate sponsor. To qualify for an internship during the academic year, the work done while in residency at the corporate sponsor must be directly related to a student's thesis/dissertation, the internship shall last for no longer than one regular academic-year semester, and the scope of the activities completed during the internship must be agreed upon by the student, the student's advisor and the corporate sponsor prior to the start of the internship. Students not meeting these requirements are not eligible for the internship registration defined below.

Graduate students completing a one semester of corporate-sponsored internship, either domestic or international, during the academic year should register for zero credit hours of off-campus work experience under the course number 597. This registration will maintain a student's full-time academic standing for the internship semester. Students registered for an internship experience under course number 597 are not assessed tuition

nor regular academic fees and as such do not have access to Mines facilities, services or staff. The Mines Health Insurance requirement applies to all students participating in an academic program (such as, but not limited to, undergraduate cooperative education, study abroad, and graduate internships) regardless of the domestic or international location of the academic program. As such, students enrolled in the Mines Health Insurance program are charged health insurance fees during their internship semester. Students participating in an international internship are required to complete the Office of International Programs paperwork in fulfillment of security and safety requirements.

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 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.

Courses completed under the reciprocal agreement may be applied to a student's degree program. 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.

Dropping and Adding Courses

Students may drop or add courses 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.

After the 11th day of classes through the 12th week, continuing students may drop any course 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 drop a course. 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.

After the 12th (or 14th) week, no drops 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 will be placed on automatic leave of absence. In order to resume their graduate program, they must submit a written application that includes documentation that the problems which caused the withdrawal have been corrected. The student will be reinstated to active status upon approval of their application by their advisor and their department head or division director.

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.

Graduation Requirements

Graduation Requirements

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 Fall and avoid summer & fall registration,
- checkout by Fall census to graduate in Fall and avoid fall registration, and
- checkout by Spring census to graduate in the Spring 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 http://gradschool.mines.edu/GS-Graduation-Information-and-Deadlines.

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 Dean of Graduate Studies prior to census. 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 department head or division or program director and the Dean of Graduate Studies. The request for a leave of absence must be in writing and must include:

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 and faculty.

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. To continue in the degree program at a later date, candidates would need to apply, and be readmitted, into 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.

The financial impact of requesting a leave of absence for the current semester is covered in the section on "Payments and Refunds (p. 9)"

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 Bulletin;
- 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 Bulletin 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 Dean of Graduate Studies and the Director of the Women in Science, Engineering and Mathematics 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, tuition at the non-resident rate will be paid by Mines for these students during their first year of study only. After the first year of study, these students may be responsible for paying the difference between resident and non-resident tuition.

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.

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 (Ph.D.)
- Chemistry (M.S.)
- Engineering Systems (M.S. and Ph.D.)
- Environmental Science & Engineering (M.S. and Ph.D.)
- Geochemistry (M.S. and Ph.D.)
- Geological Engineering (M.S., M.E., and Ph.D.)
- Hydrology (M.S. and Ph.D.)
- Mineral Economics (M.S. and Ph.D.)
- Mining and Earth Systems Engineering (M.S. and Ph.D.)
- Petroleum Engineering (M.S. and Ph.D.)

Contact the Office of Graduate Studies (http://inside.mines.edu/Graduate_School) for more information about WICHE.

Academic Regulations

2015-2016

Graduate School Bulletin

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 Bulletin 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 Bulletin is available to students in both print and electronic forms. Print bulletins are updated annually. Electronic versions of the Graduate Bulletin 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 Bulletin. This version is available at the CSM website. The electronic version of the Graduate Bulletin 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 Bulletin Provisions

If a conflict or inconsistency is found to exist between these policies and any other provision of the Mines Graduate Bulletin, 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 Bulletin 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.

Graduate students must attain a B average in deficiency courses, and any student receiving a grade of D in a deficiency course will be required to repeat the course. 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 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 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 communicate directly with the Graduate Dean or process a withdrawal form through the Graduate Office. When the form is completed, the student will receive grades of W in courses in progress. If the student does not officially withdraw the course grades are recorded as F's. 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.

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. See the Mines Undergraduate Bulletin (bulletin.mines.edu/undergraduate) for a description of this system.

In addition to these performance symbols, the following is a list of additional registration symbols that may appear on a CSM 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 not 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 (p. 13) portion of this Bulletin programs may determine that a PRU received in a course indicates unsatisfactory progress toward degree completion and 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 (p. 13) portion of this Bulletin.

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. Two to four 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 deficiency courses) taken at the Colorado School of Mines after first enrolling in a graduate degree program are included in the calculation of the overall grade point average for that program. 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 grade-point average includes all attempts at courses taken at Colorado School of Mines 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 after acceptance into a degree program. This includes both graduate and undergraduate courses. Any grade lower than "C-" is not acceptable for credit toward graduate degree requirements or graduate deficiencies.

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 discretionary dismissal as defined by the Unsatisfactory Academic Performance (p. 13) section of this Bulletin.

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 office of the EVPAA, 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 ordering diploma covers and for printing graduation invitations and programs. 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, Degree Audit form, and Admission to Candidacy form (PhD candidates only) as applicable to the degree sought.

All graduating students must officially check out of their degree program. Checkout cards may be obtained from the Graduate Office and must be completed and returned, along with all other appropriate checkout forms by the established deadline. Students must register for the graduation term, unless the checkout process is completed by census day of the graduation term.

The awarding of a degree is contingent upon the student's successful completion of all program requirements with at least a 3.000 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 in the Graduate Handbook.

Students who have completed all of their degree requirements before the specific graduation date, but who have not applied for graduation can, if necessary, request a letter from the Graduate Office certifying the completion of their programs. The student should apply for the next graduation, and the diploma will show the date of that graduation.

Graduation exercises are held in December and May. Students eligible to graduate at these times are expected to attend their respective graduation exercises. 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 will not be released by the School for any student or graduate who has an unsettled obligation of any kind to the School.

Independent Studies

To register for independent study course, a student should get from the Registrar's Office (http://inside.mines.edu/Independent-Study-Registration) the form provided for that purpose, 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 Bulletin 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.

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

For more information, please visit the Non-Degree Graduate (http://www.mines.edu/NonDegree_GS) website.

Public Access to Graduate Thesis

The award of a thesis-based graduate degree is conditioned on the student's deposit of his or her completed thesis in the Mines library to ensure its availability to the public. Although the student retains the copyright in the thesis, by depositing the thesis with the library, 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, student and Dean of Graduate Studies. 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 Statement of Work Completion form is submitted to the Graduate School.

Unsatisfactory Academic Performance

2015/2016

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 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 Dean of Graduate Studies in a timely manner. Students making unsatisfactory progress by any of the measures listed above shall be placed on academic probation upon the first occurrence of such indication. Upon the second occurrence of an unsatisfactory progress indication, the Dean shall notify the student that he or she is 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 Bulletin may be subject to immediate mandatory dismissal according to the procedure outlined below. Failure to fulfill this requirement must be reported to the Dean of Graduate Studies in a timely manner by the department head or division/program director.

Probation and Discretionary Dismissal Procedures

If a student is subject to academic probation as a result of an initial indication of unsatisfactory academic progress, the Dean of Graduate Studies shall notify the student of his or her probationary status in a timely manner.

If a student is subject to discretionary dismissal by one of the mechanisms defined above, the Dean shall notify the student 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.

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 Dean of Graduate Studies 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 be placed in non-degree status. They may request re-admission to either the same or a different degree program by submitting a full application for admission to the Graduate Office. The application will be reviewed through the normal admission process.

If a student who has been reinstated or readmitted to his or her former degree program and 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 in writing;
2. Contain a succinct description of the matter being appealed; and
3. Be filed with the Office of the Dean of Graduate Studies 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 Faculty Senate shall appoint a review committee composed of three tenured faculty members who are not members of the student's home or minor 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.

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

Exceptions and Appeals

Academic Policies and Requirements

Academic policies and requirements are included in the Bulletin 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 Bulletin 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 Dean of Graduate Studies 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 Graduate Office 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 Dean of Graduate Studies.
3. If the request involves academic policies or requirements, the Dean of Graduate Studies will request Graduate Council approval at the Council's next regularly scheduled meeting.
4. The Dean of Graduate Studies 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.
5. 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

2015-2016

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 2015-2016 academic year will be available prior to the start of the 2015-2016 academic year located at: https://inside.mines.edu/UserFiles/File/finance/budget/FY16/FY16%20Tuition%20Schedule.pdf

Fees

The official fees, approved charges, and fee descriptions for the 2014-2015 academic year will be available prior to the start of the 2014-2015 academic year and can be found at: https://inside.mines.edu/UserFiles/File/finance/budget/FY16/FY16%20Fees%20and%20Charges-FINAL.pdf

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 mail their payments to:

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

pay at the Cashier's Office in The Ben Parker Student Center. 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.

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 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

Graduate Students:

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

2015-2016

Colorado School of Mines offers post-baccalaureate programs leading to the awarding of Graduate Certificates, Professional Masters degrees, thesis and non-thesis Master of Science and 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 in two Masters degree programs may double count up to half of the course credits required for the Masters degree program with the smallest course credit hour requirement toward both degree programs. Students simultaneously enrolled in a Masters degree and Doctoral degree may double count course credits toward each degree without limit. Course credits, however, may never be applied (i.e., double counted in the case of concurrent degree enrollment or used as transfer credit in the case of sequential degree enrollment) toward more than two graduate degrees.

Before the Graduate School 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 credits are being counted toward the requirements of multiple degrees. For thesis-based students this permission should be provided by the student's thesis committee. For non-thesis and certificate programs, permission should be obtained from program coordinators or department/division chairs.

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 Bulletin.

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

- LAIS565 - 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

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 CSM 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 Bulletin.

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 CSM 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's 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's Program

CSM 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 Bulletin.

1. Academic Requirements

Each Professional Master's degree consists of a minimum of 30 total credit hours. Students must complete at least 21 credit hours at CSM 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 CSM 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 CSM 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 CSM course work.

2. Graduation Requirements

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

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

Each program publishes a list of prerequisites and core curriculum requirements for Professional Master's degrees. 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 documenting satisfactory completion of the prerequisites and core curriculum requirements. The form must have the written approval of the program offering the Professional Master's degree.

To graduate, all Professional Master's students must apply to graduate, submit a completed checkout card and a completed Statement of Work Completion from by the posted deadlines.

III. Master of Science and Engineering Programs

A. General Requirements

Graduate study at CSM 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, definition of minor programs, and the need to apply for admission to candidacy.

1. Academic Requirements

A Master's degree at Mines requires a minimum of 30 total credit hours. As part of this 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 Bulletin.

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

must not have been used as credit toward a Bachelor 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 course work and must be approved by the student's advisor, home department head, and a 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 Graduate Office, and
- complete all prerequisite and core curriculum course requirements of their department, division or program.

Each degree program publishes a list of prerequisite and core curriculum requirements for that 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.

Upon completion of the above defined requirements, students must submit Degree Audit form documenting satisfactory completion of the prerequisite and core curriculum requirements and granting permission to begin Master's level research. 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 Engineering students must apply to graduate, submit a completed checkout card, a Statement of Work Completion form, and all thesis-based students must submit a completed Regulated Materials form by the posted 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 Bulletin for more information. Although non-thesis master's students are not assigned a Thesis Committee, students in this program do select a faculty advisor, subject to the approval of the student's home department.

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 Graduate School.

1. Faculty Advisor Appointment

Each thesis-based Master's student must select a faculty advisor to provide advice regarding the student's thesis direction, research and selection of courses. Master's students must select faculty advisors by the end of the second semester at CSM. Advisors must be full-time permanent members of the CSM faculty. In this context, full-time permanent members of the CSM 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.

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 appoints a Thesis Committee whose members have been recommended by the student, the student's faculty advisor, and the student's department head. Students should have a thesis committee appointed 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. Of these Committee members, two must be from the home department or, in the case of interdisciplinary degree programs, an allied department. Off-campus members can be assigned to the Committee to 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. If a thesis co-advisor is assigned, an additional faculty member from the home or allied department must be added to the committee. Students who choose to have a minor program at the Master's level must select a representative from their minor area of study to serve on the Thesis Committee. Minor representatives must be full-time members of the CSM faculty.

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:

1. The chairperson cannot be the student's advisor or co-advisor and
2. The chairperson must be a full-time CSM 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 in the Office of Graduate Studies and should be obtained before beginning work on the thesis.)

4. Time Limitations

A candidate for a thesis-based Masters 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 Dean of Graduate Studies. 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 Dean of Graduate Studies 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 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.

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 Bulletin.

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 Dean of Graduate Studies. 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. 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 CSM.

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

Each doctoral student must select a faculty advisor to advise with respect to the student's thesis direction and research and selection of courses. Doctoral students must select faculty advisors by the end of the second semester at CSM. Advisors must be full-time permanent members of the CSM faculty. In this context, full-time permanent members of the CSM 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.

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 appoints a Doctoral Thesis Committee whose members have been recommended by the student's doctoral degree program. Students should have a thesis committee appointed by the end of their second semester. 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 full-time permanent CSM faculty members.

3. The fourth, required member of the Committee must be a full-time permanent CSM faculty member, may not be an advisor, 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 minor field is designated, an additional committee member must be included who is an expert in that field. Minor representatives must be full-time permanent members of the CSM faculty who are participating members of the minor program area. If multiple minor programs are pursued, each must have a committee representative as defined above.

5. 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 shy;Committee members including, but not limited to, attenshy;dance 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.

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 a thesis committee appointment 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.

Each degree program publishes a list of prerequisite and core curriculum requirements for that 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. 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 Bulletin on Graduate Degree Programs and Description of Courses.

Upon completion of these requirements, students must submit a Degree Audit form and an Admission to Candidacy form documenting satisfactory completion of the prerequisite and core curriculum requirements and

granting permission to begin doctoral research. The form must have the written approval of all members of the Ph.D. Committee.

To graduate, all PhD students must apply to graduate, submit a completed checkout card, submit a completed Statement of Work Completion form, submit a completed Regulated Materials form and complete the Survey of Earned Doctorate by the posted 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. (Students should obtain a copy of these guidelines from the Office of Graduate Studies 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 Dean of Graduate Studies. 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 Dean of Graduate Studies 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 there 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 CSM 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.

Certain 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 course credits which also were used in fulfilling the requirements of their undergraduate degree. These courses may only be applied toward fulfilling Doctoral degree or, Master's degree requirements beyond the institutional minimum Master's degree requirement of 30 credit hours. Courses must meet all requirements for graduate credit, but their grades are not included in calculating the graduate GPA. Check the departmental section of the Bulletin to determine which programs provide this opportunity.

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 Bulletin.

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 Bulletin, 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 Bulletin 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 notify the Registrar of the intent to do so at the time of enrollment in the course. The Registrar will forward this 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. If an undergraduate student has not been admitted into a graduate program, all 500-level graduate courses taken as an undergraduate Combined Degree Program student will be applied to the student's undergraduate degree transcript. If these are not used toward an undergraduate degree requirement, they may, with program consent, be applied to a graduate degree program as transfer credit. All regular regulations and limitations regarding the use of transfer credit to a graduate degree program apply to these credits.

Applied Mathematics & Statistics

2015-2016

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

Willy Hereman, Professor

Professors

Bernard Bialecki

Mahadevan Ganesh

Paul A. Martin

Barbara M. Moskal

William Navidi

Associate Professor

Luis Tenorio

Assistant Professors

Paul Constantine

Cecilia Diniz Behn

Amanda Hering

Stephen Pankavich

Aaron Porter

Teaching Professors

G. Gustave Greivel

Scott Strong

Teaching Associate Professors

Terry Bridgman

Debra Carney

Holly Eklund

Mike Mikucki

Mike Nicholas

Jennifer Strong

Rebecca Swanson

Emeriti Professors

William R. Astle

Norman Bleistein

Ardel J. Boes

Austin R. Brown

John A. DeSanto

Graeme Fairweather

Raymond R. Gutzman

Frank G. Hagin

Donald C.B. Marsh

Steven Pruess

Emeriti Associate Professors

Barbara B. Bath

Ruth Maurer

Robert G. Underwood

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. 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. 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. Prerequisite: MATH225 or MATH235 and MATH332 or MATH 342 or equivalent courses. 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. MATH424 or MATH531.

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.
(I) Modern extensions of the standard linear model for analyzing data. Topics include generalized linear models, generalized additive models, mixed effects models, and resampling methods. Prerequisite: MATH 335 and MATH 424. 3 hours lecture; 3.0 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. Prerequisites: MATH 534. 3 hours lecture and discussion; 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. Prerequisite: MATH335 or MATH535.

MATH540. PARALLEL SCIENTIFIC COMPUTING. 3.0 Semester Hrs.
(I) 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: MATH407, CSCI407. 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. Prerequisite: MATH332 or MATH342, and MATH455.

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

Department Website - cee.mines.edu

2015-2016

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 four different emphasis areas: Engineering Mechanics (EM), 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 engineering mechanics, 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.

Engineering Mechanics: Engineering Mechanics is an interdisciplinary emphasis area offered with the Department of Mechanical Engineering. Engineering mechanics is concerned with the development and implementation of numerical and analytical procedures to simulate materials' expected behaviors. This emphasis area draws upon synergistic teaching and research strengths in the Departments of Civil and Environmental Engineering and Mechanical Engineering and offers options to take courses in Materials Science, Mathematics, and Computer Science. The skills developed in this emphasis area may be used for a wide range of applications in multiple engineering and science disciplines, including (but not limited to) structural mechanics, geomechanics, fluid mechanics, solid mechanics, hydrology, and physics. Students who pursue this discipline typically complete the requirements of the Engineering Mechanics (EM) emphasis area in the CEE degree.

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 bulletin). 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 bulletin, 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. The CSM 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 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 (CEEN 599) 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 (p. 52): 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 CEEN564 Environmental Toxicology
- 3-credit Independent Study (CEEN 599) 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 four emphasis areas: Environmental and Water Engineering, Engineering, Engineering Mechanics, 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 21elective 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 CEEN 590 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	ANALYSIS AND DESIGN OF TUNNELS IN SOFT GROUND (*)	3.0

 * 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 CEEN 596 Environmental Seminar:

Chemistry: CEEN550 Principles of Env Chemistry

Physical Transport: CEEN580 Env Pollution

Bio Processes: CEEN560 Molecular Microbial Ecology
or CEEN562 Geomicrobial Systems or CEEN564 Env Toxicology

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 CEEN 590 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

ENGINEERING MECHANICS

Additional Prerequisites Courses: Mechanics of materials, fluid mechanics

 EM Core Courses: Four core courses (12 credits), each one selected from each one of the following four topical areas, plus CEEN 590 Civil Engineering seminar:

1. Mechanics of Solid Materials
2. Mechanics of Fluid or Multiphase Materials
3. Numerical and Computational Methods
4. Analytical Applied Mathematical Methods

Topical Area: Mechanics of Solid Materials

MLGN501	STRUCTURE OF MATERIALS	3.0
MLGN505	MECHANICAL PROPERTIES OF MATERIALS	3.0
MEGN510	SOLID MECHANICS OF MATERIALS (*)	3.0
MEGN511	FATIGUE AND FRACTURE	3.0
MEGN512	ADVANCED ENGINEERING VIBRATION	3.0
CEEN512	SOIL BEHAVIOR	3.0
CEEN530	ADVANCED STRUCTURAL ANALYSIS (*)	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

Topical Area: Mechanics of Fluids and Multiphase Materials

MEGN520	BOUNDARY ELEMENT METHODS	3.0
MEGN521	INTRODUCTION TO DISCRETE ELEMENT METHODS (DEMS)	3.0
MEGN593	ENGINEERING DESIGN OPTIMIZATION (*)	3.0
CEEN505	NUMERICAL METHODS FOR ENGINEERS	3.0
CEEN506	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN582	MATHEMATICAL MODELING OF ENVIRONMENTAL SYSTEMS (*)	3.0

*Design Course

Topical Area: Numerical and Computational Methods

MEGN552	VISCOUS FLOWAND BOUNDARY LAYERS	3.0
MEGN553	INTRODUCTION TO COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS AND TRANSPORT PHENOMENA	3.0
CEEN481	HYDROLOGIC AND WATER RESOURCES ENGINEERING	3.0
CEEN510	ADVANCED SOIL MECHANICS (*)	3.0
CEEN511	UNSATURATED SOIL MECHANICS	3.0
CEEN514	SOIL DYNAMICS (*)	3.0
CEEN515	HILLSLOPE HYDROLOGY AND STABILITY (*)	3.0
CEEN584	SUBSURFACE CONTAMINANT TRANSPORT	3.0
CEEN611	MULTIPHASE CONTAMINANT TRANSPORT	3.0

*Design Course

Topical Area: Analytical Applied Mathematical Methods

MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0

MEGN502　　ADVANCED ENGINEERING ANALYSIS　　3.0

Department Head

John E. McCray

Professors

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Terri Hogue

Tissa Illangasekare, AMAX Distinguished Chair

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Panos Kiousis

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Candace Sulzbach, Emeritus Teaching Professor

Teaching Associate Professors

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Susan Reynolds

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Teaching Assistant Professor

Jeffery Holley

Adjunct Faculty

Sidney Innerebner

Paul B. Queneau

Tanja Rauch

Patrick Ryan

Research Assistant Professors

Mengistu Geza

Lee Landkamer

Dong Li

Courses

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.

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. ANALYSIS AND DESIGN OF TUNNELS IN SOFT GROUND. 3.0 Semester Hrs.
(I) Analysis and design of new and existing water, wastewater, transportation and utility tunnels in soft ground conditions (soil). Addresses geotechnical site characterization, selection of design parameters, and stability and deformation analysis of ground, utilities and overlying structures. Includes design of lining and ground support systems 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. Prerequisites: Undergraduate Introduction to Geotechnical Engineering course (i.e., similar to CEEN312). 3 hours lecture and discussion; 3 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.
(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.

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. ENVIRONMENTAL POLLUTION: SOURCES, CHARACTERISTICS, TRANSPORT AND FATE. 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.

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 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.

CEEN597. SPECIAL SUMMER COURSE. 6.0 Semester Hrs.

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.

CEEN599AA. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AB. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AC. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AD. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AE. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AF. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AG. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AH. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AI. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AJ. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AK. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AL. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AM. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AN. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AO. INDEPENDENT STUDY. 0.5-6 Semester Hr.

CEEN599AP. INDEPENDENT STUDY. 0.5-6 Semester Hr.

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.

Electrical Engineering & Computer Science

2015-2016

Degrees Offered

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

Program Overview

The Electrical Engineering and Computer Science Department (EECS) offers the degrees Master of Science and Doctor of Philosophy in Computer Science and 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 Department also supports graduate degrees in Mathematical and Computer Sciences (computer science option) and Engineering (electrical specialty), but these degrees have been retired. For details on these programs, please see the 2011-2012 CSM Graduate Bulletin. Students admitted to the Mathematical and Computer Sciences (computer science option) or Engineering (electrical specialty) graduate programs for the 2012-2013 academic year may opt to change their program of study to EE or CS as appropriate with their background and complete the degree requirements for the selected degree.

The EECS department has nine areas of research activity that stem from the core fields of Electrical Engineering and Computer Science: (1) Antennas and Wireless Communications, (2) Applied Algorithms and Data Structures, (3) Education (4) Energy Systems and Power Electronics, (5) High Performance Computing, (6) Human-Centered Robotics, (7) Information and Systems Sciences, (8) Machine Learning, and (9) Networking. Additionally, students may study areas such as Embedded Systems and/or Robotics, which include elements from both Computer Science and Electrical Engineering disciplines. In many cases, individual research projects encompass more than one research area.

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.

Applied Algorithms and Data Structures is an interdisciplinary research area that is applied to areas such as VLSI design automation, cheminformatics, computational materials, and cyber-physical systems.

Education research includes areas within STEM education and K-12 education.

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.

High Performance Computing research is focused on compiler-based code and data transformation, memory optimization for both multi-core and many-core processors, speculative parallelization, approximate computation and GPU-based acceleration of Big Data applications (such as graph processing and machine learning algorithms).

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.

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.

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.

Networking research includes mobile networks, sensor networks, pervasive computing, and wireless networking. Focus areas include credible network simulation, cyber-physical systems, game theoretic algorithm design, middleware, and mobile social applications. Interdisciplinary research also exists, mainly in the use of wireless sensor networks for environmental monitoring and development of energy efficient buildings.

Program Details

The EECS Department offers the degrees Master of Science and Doctor of Philosophy in Computer Science and 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 EECS 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. This program is described in the undergraduate catalog and is in place for both Computer Science and Electrical Engineering students. The Physics combined program also offers a track in Electrical Engineering. Details on this program can be found in the CSM Undergraduate Bulletin, and course schedules for this program can be obtained in the Physics Department.

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.

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 EECS 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 EECS 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 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.

Advisor and Thesis Committee: Students must have an Advisor from the EECS 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 EECS faculty by rank is available in the faculty section (p.   ) of the bulletin.

Master of Science (thesis option) students in both EE and CS must have at least three members on their Thesis Committee; the Advisor and one other member must be permanent faculty in the EECS Department. Both EE and 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 EECS 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 CSM 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 36 credit hours. Requirements for the thesis M.S. are 24 hours of coursework plus 12 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 30 hours of coursework plus 6 hours of project credit; requirements for the Coursework Track are 36 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

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 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 EECS 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.

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)		12.0
EE CORE: EE Core Courses (ESPE track)		6.0
EE CORE: EE Core Courses (ISS track)		12.0

TECHNICAL ELECTIVES ^{Technical Electives must be approved by Thesis Committee} — rendered as: TECHNICAL ELECTIVES [Technical Electives must be approved by Thesis Committee]

EE TECH: EE Technical Electives (AWC track)	12.0
EE TECH: EE Technical Electives (ESPE track)	18.0
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)	12.0
EE CORE: EE Core Courses (ESPE track)	6.0
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)	12.0
EE TECH: EE Technical Electives (ESPE track)	18.0
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)		12.0
EE CORE: EE Core Courses (ESPE track)		6.0
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)		24.0
EE TECH: EE Technical Electives (ESPE track)		30.0
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 EECS 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 3 the following courses.

Advanced Engineering Electromagnetics
Computational Electromagnetics
Antennas

and choose at least one of the following:

EENG515	MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS	3.0
EENG527	WIRELESS COMMUNICATIONS	3.0
EENG535	RF AND MICROWAVE ENGINEERING	3.0
Radar Systems (to be approved for 2015-16 academic year)		

Required Core: Energy Systems and Power Electronics Track

Choose at least 2 of the following:

EENG570	ADVANCED HIGH POWER ELECTRONICS	3.0
EENG580	POWER DISTRIBUTION SYSTEMS ENGINEERING	3.0

EENG581	POWER SYSTEM OPERATION AND MANAGEMENT	3.0

Required Core: Information and Systems Sciences Track

All students must take:

EENG515	MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS	3.0

and choose at least 3 of the following:

EENG509	SPARSE SIGNAL PROCESSING	3.0
EENG510	IMAGE AND MULTIDIMENSIONAL SIGNAL PROCESSING	3.0
EENG517	THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS	3.0
EENG519	ESTIMATION THEORY AND KALMAN FILTERING	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MEGN544	ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL	3.0

Other EE Courses:

EENG512	COMPUTER VISION	3.0
EENG535	RF AND MICROWAVE ENGINEERING	3.0
MEGN540	MECHATRONICS	3.0
MEGN545	ADVANCED ROBOT CONTROL	3.0
EGGN589	DESIGN AND CONTROL OF WIND ENERGY SYSTEMS	3.0
EENG617	INTELLIGENT CONTROL SYSTEMS	3.0
EENG618	NONLINEAR AND ADAPTIVE CONTROL	3.0
EENG683	COMPUTER METHODS IN ELECTRIC POWER SYSTEMS	3.0

Interium Department Head and Professor

Atef Elsherbeni, Dobelman Chair

Professors

Kevin Moore, College Dean

Tracy Camp

Randy Haupt

Dinesh Mehta

P.K. Sen

Tyrone Vincent

Associate Professors

Qi Han

William Hoff

Kathryn Johnson

Marcelo Simoes

Michael Wakin

Assistant Professors

Salman Mohagheghi

Payam Nayeri

Gongguo Tang

Hua Wang

Bo Wu

Dejun Yang

Chuan Yue

Hao Zhang

Teaching Professors

Ravel Ammerman

Vibhuti Dave

Cyndi Rader

Jeff Schowalter

Teaching Associate Professors

Stephanie Claussen

Keith Hellman

Christopher Painter-Wakefield

Jeffrey Paone

Emeritus Associate Professor

Catherine Skokan

Courses

CSCI510. IMAGE AND MULTIDIMENSIONAL SIGNAL PROCESSING. 3.0 Semester Hrs.
Equivalent with EGGN510,
(I) This course provides the student with the theoretical background to allow them to apply state of the art image and multi-dimensional signal processing techniques. The course teaches students to solve practical problems involving the processing of multidimensional data such as imagery, video sequences, and volumetric data. The types of problems students are expected to solve are automated mensuration from multidimensional data, and the restoration, reconstruction, or compression of multidimensional data. The tools used in solving these problems include a variety of feature extraction methods, filtering techniques, segmentation techniques, and transform methods. Students will use the techniques covered in this course to solve practical problems in projects. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, Fourier transforms, and a programming language. 3 hours lecture; 3 semester hours.

CSCI512. COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with EGGN512,
(II) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course concentrates on how to recover the structure and properties of a possibly dynamic three-dimensional world from its two-dimensional images. We start with an overview of image formation and low level image processing, including feature extraction techniques. We then go into detail on the theory and techniques for estimating shape, location, motion, and recognizing objects. Applications and case studies will be discussed from scientific image analysis, robotics, machine vision inspection systems, photogrammetry, multimedia, and human interfaces (such as face and gesture recognition). Design ability and hands-on projects will be emphasized, using image processing software and hardware systems. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, and a programming language. 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.
(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,
(I) 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 (or equivalent). 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.

CSCI586. FAULT TOLERANT COMPUTING. 3.0 Semester Hrs.
This course provides a comprehensive overview of fault tolerant computing including uniprocessor fault tolerance, distributed fault tolerance, failure model, fault detection, checkpoint, message log, algorithm-based fault tolerance, error correction codes, and fault tolerance in large storage systems. 3 hours lecture; 3 semester hours.

CSCI597. SUMMER PROGRAMS. 6.0 Semester Hrs.

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.

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.

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.

EENG510. IMAGE AND MULTIDIMENSIONAL SIGNAL PROCESSING. 3.0 Semester Hrs.
Equivalent with CSCI510,EGGN510,
(I) This course provides the student with the theoretical background to allow them to apply state of the art image and multi-dimensional signal processing techniques. The course teaches students to solve practical problems involving the processing of multidimensional data such as imagery, video sequences, and volumetric data. The types of problems students are expected to solve are automated mensuration from multidimensional data, and the restoration, reconstruction, or compression of multidimensional data. The tools used in solving these problems include a variety of feature extraction methods, filtering techniques, segmentation techniques, and transform methods. Students will use the techniques covered in this course to solve practical problems in projects. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, Fourier transforms, and a programming language. 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. Prerequisites: EENG311 and EENG511. 3 hours lecture; 3 semester hours.

EENG512. COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI512,EGGN512,
(II) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course concentrates on how to recover the structure and properties of a possibly dynamic three-dimensional world from its two-dimensional images. We start with an overview of image formation and low level image processing, including feature extraction techniques. We then go into detail on the theory and techniques for estimating shape, location, motion, and recognizing objects. Applications and case studies will be discussed from scientific image analysis, robotics, machine vision inspection systems, photogrammetry, multimedia, and human interfaces (such as face and gesture recognition). Design ability and hands-on projects will be emphasized, using image processing software and hardware systems. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, and a programming language. 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 Prerequisite: EENG417. 3 hours lecture; 3 semester hours.

EENG519. ESTIMATION THEORY AND KALMAN FILTERING. 3.0 Semester Hrs.
Equivalent with EGGN519,
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. Pre-requisite: EENG515 and MATH534 or equivalent. Spring semester of odd years. 3 Lecture Hours; 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.

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.

EENG535. RF AND MICROWAVE ENGINEERING. 3.0 Semester Hrs.
Equivalent with EGGN516,
This course teaches the basics of RF/microwave design including circuit concepts, modeling techniques, and test and measurement techniques, as applied to wireless communication systems. RF/microwave concepts that will be discussed are: scattering parameters, impedance matching, microstrip and coplanar transmission lines, power dividers and couplers, filters, amplifiers, oscillators, and diode mixers and detectors. Students will learn how to design and model RF/microwave components such as impedance matching networks, amplifiers and oscillators on Ansoft Designer software, and will build and measure these circuits in the laboratory. Prerequisites: EENG385, EENG386, EENG413. 3 hours lecture, 3 semester hours. Taught on demand.

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 STABILITY. 3.0 Semester Hrs.
Advanced topics on stability of power and energy systems, including dynamic modeling of generators and motors, small signal stability of power system, transient stability during and in the aftermath of disturbances, voltage suability and voltage collapse, blackouts and brownouts in the bulk power grid, subsynchronous resonance, and impacts of distributed and renewable energy resources on grid stability. Prerequisites: EENG480, EENG481. 3 hours of lecture; 3 credit hours. Spring, even years.

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.

EENG597. SUMMER PROGRAMS. 6.0 Semester Hrs.

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.

SYGN555. SMARTGEO SEMINAR. 1.0 Semester Hr.
Geosystems are natural or engineered earth structures, e.g. earth dams or levees, groundwater systems, underground construction sites, and contaminated aquifers. An intelligent geosystem is one that can sense its environment, diagnose its condition/state, and provide decision support to improve the management, operation, or objective of the geosystem. The goal of this course is to introduce students to topics that are needed for them to be successful working in a multi-disciplinary field. The course will include training in leadership, multidisciplinary teams, policy and ethical issues, and a monthly technical seminar. Prerequisite/Corequisite: SYGN550. 1 hour lecture; 1 semester hour credit.

Mechanical Engineering

2015-2016

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. See the information that follows for full details on these degrees.

Combined Program:

The ME Department also offers combined BS/MS degree programs. These programs enable students to begin graduate coursework while still finishing their undergraduate degree requirements. This program is described in the undergraduate catalog. In addition, the combined degree program is offered in collaboration with the Physics Department and allows students to obtain specific engineering skills that complement their physics background. Details on the combined programs can be found in the CSM Undergraduate Bulletin, and course schedules for the programs can be obtained in the Mechanical Engineering, and Physics Departments.

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.

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. 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.

Ph.D. 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.

Degree Audit and Admission to Candidacy: Master students must complete the Degree Audit form (http://gradschool.mines.edu/Degree-Audit) by the posted deadlines. 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) two weeks prior to census day of 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.

Time Limit: As stipulated by the CSM 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.

Degree Requirements

The Master of Science degree in Mechanical Engineering (thesis or non-thesis option) requires 30 credit hours. Requirements for the M.S. 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.

The Ph.D. in Mechanical Engineering degree 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.

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
ME TECH	Technical Electives Courses approved by Thesis Committee.	9.0
ME CORE	Courses from ME Course List	3.0
MEGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	6.0
Total Semester Hrs		**30.0**

M.S. Non-Thesis Degree

MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
RESEARCH CORE	Course from one Research Division List	9.0
ME TECH	Technical Electives Courses must be approved by Advisor.	9.0

ME CORE	Courses from ME Course List	9.0
Total Semester Hrs		**30.0**

Ph.D. 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
ME TECH	Technical Electives Must be approved by the Thesis Committee.	24.0
MEGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	30.0

RESEARCH DIVISION COURSES

BIOMECHANIC COURSES

MEGN531	PROSTHETIC AND IMPLANT ENGINEERING
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS
MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT
MEGN536	COMPUTATIONAL BIOMECHANICS

ROBOTICS, AUTOMATION AND DESIGN

MEGN540	MECHATRONICS
MEGN544	ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL
MEGN545	ADVANCED ROBOT CONTROL
MEGN591	ADVANCED ENGINEERING DESIGN METHODS
MEGN593	ENGINEERING DESIGN OPTIMIZATION
MEGN592	RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN

SOLID MECHANICS AND MATERIALS

MEGN512	ADVANCED ENGINEERING VIBRATION
MEGN514	CONTINUUM MECHANICS
MEGN598	MICROMECHANICS/HOMOGENIZATION
MEGN598	NONLINEAR MECHANICS
MEGN598	COMPUTATIONAL MECHANICS

THERMAL-FLUID SYSTEMS

MEGN501	ADVANCED ENGINEERING MEASUREMENTS
MEGN552	VISCOUS FLOWAND BOUNDARY LAYERS
MEGN553	INTRODUCTION TO COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS AND TRANSPORT PHENOMENA
MEGN566	COMBUSTION
MEGN571	ADVANCED HEAT TRANSFER

ME COURSE LIST

Any graduate level course taught by a member of the CSM Mechanical Engineering faculty is considered a part of the list of acceptable Mechanical Engineering courses.

Professor and Department Head

Gregory S. Jackson

George R. Brown Distinguished Professor

Robert J. Kee

Professors

John R. Berger

Cristian V. Ciobanu

Graham G.W. Mustoe

Alexandra Newman

Associate Professor

Joel M. Bach

Robert Braun

Anthony J. Petrella

John P.H. Steele

Neal Sullivan

Cameron Turner

Ruichong "Ray" Zhang

Assistant Professor

Gregory Bogin

Ozkan Celik

Steven DeCaluwe

Jason Porter

Anne Silverman

Aaron Stebner

Paulo Tabares-Velasco

Nils Tilton

Douglas Van Bossuyt

Xiaoli Zhang

Teaching Associate Professors

Robert Amaro

Jennifer Blacklock

Jered Dean

Ventzi Karaivanov

Leslie M. Light

Derrick Rodriguez

Emeriti Professor

Robert King

Michael B. McGrath

Emerita Professor

Joan P. Gosink

Emeritus Associate Professor

Dave Munoz

Research Professor

George Gilmer

Research Associate Professor

Huayang Zhu

Research Assistant Professors

Christopher B. Dreyer

Branden Kappes

Sandrine Ricote

Affiliate Professor of Mechanical Engineering

Michael Mooney

Courses

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.

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.

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.

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.

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.

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.

MEGN587. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.
(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.
(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.

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.

Economics and Business

2015-16

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	18.0
Approved electives*	18.0
Total Semester Hrs	**36.0**

Thesis option

Core courses	18.0
Research credits	12.0
Approved electives*	6.0
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 Earth Resources Institute 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	18.0
Extended Core plus Research Methods	12.0
Approved electives	18.0
Total Semester Hrs	**48.0**

Research credits

Research credits	24.0

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). Exams covering the Micro Economics (Micro) and Quantitative Methods (Quant) portions of the core will be offered between semesters, during the summer and winter breaks. The Micro examination will include topics covered in EBGN 511 and EBGN 521, and the Quant examination will include topics covered in EBGN 509 and EBGN 590. A student will receive one of four possible grades on the Micro and Quant 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). The examination will include topics from EBGN 611, Advanced Microeconomics, and two other 600-level courses, which the student chooses as their extended core. 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 EBGN511 in the first fall semester of study; and EBGN 521 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
EBGN511	MICROECONOMICS	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		**18.0**

b. Approved Electives (18 credits for M.S. non-thesis option or 12 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 at the 600 level (one course for thesis students). 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
EBGN511	MICROECONOMICS	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		**18.0**

b. Extended Core Courses and Research Methods

EBGN611	ADVANCED MICROECONOMICS	3.0
EBGN600-level course		3.0
EBGN600-level course		3.0
EBGN695	RESEARCH METHODOLOGY	3.0
Total Semester Hrs		**12.0**

Engineering and Technology Management Program (ETM) 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 at least one full-time equivalent semester in the program.

Non-thesis option	
Core courses	12.0
Credits from one or both specializations	18.0
Total Semester Hrs	**30.0**

Thesis option	
Core courses	12.0
Research credits	6.0
Credits from one or both specializations	12.0
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 faculty advisor.

Further Degree Requirements

All thesis and non-thesis ETM Program students have three additional degree requirements:

1. the "Executive-in-Residence" seminar series;
2. the ETM Communications Seminar;
3. the Leadership and Team Building Exercise.

All students are required to attend the ETM Program "Executive-in-Residence" seminar series during at least one semester of their attendance at CSM. 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 5-7 one hour seminars on a variety of topics related to leadership and strategy in the engineering and technology sectors. In addition, all students are required to attend a two-day Communications Seminar in their first fall semester of study in the ETM Program. The seminar will provide students 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. The Communications Seminar is designed to better prepare students for the ETM learning experience, as well as their careers in industry. Finally, all students are required to attend a one-day Leadership and Team Building Exercise in their first fall semester of study in the ETM Program. This course will consist of non-competitive games, trust exercises and problem solving challenges. This exercise will introduce students to one another and provide some opportunity to learn and practice leadership and team skills.

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 Chair of the ETM Program.

Required Curriculum M.S. Degree Engineering and Technology Management

Thesis and non-thesis students are required to complete the following 12 hours of core courses:

a. Core Courses

EBGN525	OPERATIONS RESEARCH: DETERMINISTIC OPTIMIZATION	3.0
EBGN540	ACCOUNTING AND FINANCE	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		**12.0**

b. Areas of Focus (18 credits required for non-thesis option or 9 credits required for thesis option)

Engineering Management and Optimization Methods

EBGN526	OPERATIONS RESEARCH: STOCHASTIC MODELING	3.0
EBGN528	INDUSTRIAL SYSTEMS SIMULATION	3.0
EBGN559	SUPPLY CHAIN MANAGEMENT	3.0
EBGN560	DECISION ANALYSIS	3.0
EBGN555	LINEAR PROGRAMMING	3.0

Technology Management and Innovation

EBGN515	ECONOMICS AND DECISION MAKING	3.0
EBGN553	PROJECT MANAGEMENT	3.0
EBGN564	MANAGING NEW PRODUCT DEVELOPMENT	3.0
EBGN565	MARKETING FOR TECHNOLOGY-BASED COMPANIES	3.0
EBGN566	TECHNOLOGY ENTREPRENEURSHIP	3.0
EBGN572	INTERNATIONAL BUSINESS STRATEGY	3.0
EBGN598	SPECIAL TOPICS IN ECONOMICS AND BUSINESS	3.0

Professors

John T. Cuddington, Research Professor

Graham A. Davis, William J. Coulter Professor

Roderick G. Eggert, Professor

Michael R. Walls, Division Director and Professor

Associate Professors

Edward J. Balistreri

Jared C. Carbone

Michael B. Heeley

Steffen Rebennack

Assistant Professors

Harrison Fell

Ian A. Lange

Peter Maniloff

Teaching Associate Professors

Scott Houser

Becky Lafrancois

Mark Mondry

John M. Stermole

Professors Emeriti

Carol A. Dahl

Franklin J. Stermole

John E. Tilton

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) This is a first-semester graduate courses 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 (co-requisite). 3 hours lecture and discussion; 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.
(II) The second of two courses dealing with applied microeconomic theory. This part concentrates on the behavior of the minerals and energy segment of the economy, the theory of production and cost, derived demand, price and output level determination by firms, and the competitive structure of product and input markets. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBGN509, EBGN510; EBGN511.

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. OPERATIONS RESEARCH: DETERMINISTIC OPTIMIZATION. 3.0 Semester Hrs.
This course provides a scientific approach to planning and decision making problems that arise in business. The course covers deterministic optimization models such as linear programming, non-linear programming, integer programming, and network modeling. Applications of the models are covered using spreadsheets. The intent of the course is to enhance logical modeling ability and to develop quantitative managerial and spreadsheet skills. The models cover applications in the areas of earth, energy, production, logistics, work force scheduling, marketing and finance. 3 lecture hours, 3 semester hours.

EBGN526. OPERATIONS RESEARCH: STOCHASTIC MODELING. 3.0 Semester Hrs.
As a survey course in stochastic modeling, this course covers a range of topics including an introduction and review of probability models (e.g., sample spaces, events, conditional probabilities, Bayes' formula), and of random variables; and, some subset of the following topics: (i) Markov chains, (ii) Queuing Theory, (iii) Reliability Theory, (iv) Brownian motion, and (v) Simulation. 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 hour 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) 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: Principles of Microeconomics, MATH111, EBGN509, EBGN510, EBGN511. 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.
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. Prerequisite: EBGN504.

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 RESEARCH. 3.0 Semester Hrs.
The purpose of this course is to gain a deep understanding of the marketing research decisions facing product managers in technology based companies. While the specific responsibilities of a product manager vary across industries and firms, three main activities common to the position are: (1) analysis of market information, (2) marketing strategy development, and (3) implementing strategy through marketing mix decisions. In this course students will develop an understanding of available marketing research methods and the ability to use marketing research information to make strategic and tactical decisions. Prerequisite: MATH530.

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.

EBGN574. INVENTING, PATENTING, AND LISCENSING. 3.0 Semester Hrs.
The various forms of intellectual property, including patents, trademarks, copyrights, trade secrets and unfair competition are discussed; the terminology of inventing, patenting and licensing is reviewed, and an overview of the complete process is given; the statutes most frequently encountered in dealing with patents (35 USC ?101, ?102, ?103 and ? 112) are introduced and explained; the basics of searching the prior art are presented; participants 'walk through' case histories illustrating inventing, patenting, licensing, as well as patent infringement and litigation; the importance of proper documentation at all stages of the process is explained; the "do's" and "don't" of disclosing inventions are presented; various types of agreements are discussed including license agreements; methods for evaluating the market potential of new products are presented; the resources available for inventors are reviewed; inventing and patenting in the corporate environment are discussed; the economic impacts of patents are addressed. Prerequisite: None. Offered in Field session and Summer session only.

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.

EBGN635. SEE EBGN535. 3.0 Semester Hrs.

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.

EBGN675. SEE EBGN575. 3.0 Semester Hrs.

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.

EBGN694. SEE EBGN694. 3.0 Semester Hrs.

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

- Professional Master Degree (Petroleum Reservoir Systems) (Non-Thesis)
- Professional Master Degree (Mineral Exploration) (Non-Thesis)
- Master of Engineering (Geological Engineer) (Non-Thesis)
- Master of Science (Geology)
- Master of Science (Geological Engineering)
- Doctor of Philosophy (Geology)
- Doctor of Philosophy (Geological Engineering)

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.

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 will require a minimum of 72 hours of course and research credit hours (a maximum of 9 credit hours may be 400-level course work). All students must complete:

Course work	48.0
Research	24.0
Total Semester Hrs	**72.0**

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)."

To ensure breadth of background, the course of study to the degree of Doctor of Philosophy (Geology) must include at least one graduate course in each of the fields of stratigraphy/sedimentology, structural geology/tectonics, and petrology (this breadth requirement may be satisfied by courses already taken as part of a Master of Science degree). At the discretion of the student's Doctoral Thesis Advisory Committee, an appropriate course may be substituted for one (and only one) of the fields above. All Doctor of Philosophy (Geology) students must pass a qualifying examination and must 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 Doctoral Thesis Advisory Committee before the student begins substantial work on the thesis research.

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 hours must consist of:

GPGN/ PEGNnull419	WELL LOG ANALYSIS AND FORMATION EVALUATION	3.0
or GPGN/ PEGNnull519	ADVANCED FORMATION EVALUATION	
Select two of the following:		6.0
GEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	
or GPGN439	GEOPHYSICS PROJECT DESIGN / MULTIDISCIPLINARY PETROLEUM DESIGN	
or PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	
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**

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. 12) 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	ADVANCED GROUNDWATER ENGINEERING	
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	ENVIRONMENTAL POLLUTION: SOURCES, CHARACTERISTICS, TRANSPORT AND FATE	
GEGN509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	
GEGN581	ADVANCED GROUNDWATER ENGINEERING	
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	ADVANCED GROUNDWATER ENGINEERING	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 or GEGN467	ENGINEERING GEOLOGY AND GEOTECHNICS GROUNDWATER ENGINEERING	4.0
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

Paul M. Santi

Professors

Wendy J. Harrison

Murray W. Hitzman, Charles F. Fogarty Professor of Economic Geology

Reed M. Maxwell

Stephen A. Sonnenberg, Charles Boettcher Distinguished Chair in Petroleum Geology

Richard F. Wendlandt

Lesli J. Wood, Weimer Distinguished Chair and Professor, Geology

Associate Professors

David A. Benson

Jerry D. Higgins

John D. Humphrey

Thomas Monecke

Piret Plink-Bjorklund

Kamini Singha, Joint appointment with Civil and Environmental Engineering

Bruce Trudgill

Wei Zhou

Assistant Professors

Alexander Gysi

Yvette Kuiper

Alexis Sitchler

Gabriel Walton

Teaching Associate Professor

Christian V. Shorey

Research Professors

David Pyles

J. Frederick (Rick) Sarg

Research Associate Professors

Donna S. Anderson

Nicholas B. Harris

Karin Hoal

Research Assistant Professors

Jennifer L. Aschoff

Jeremy Boak

Maeve Boland

Mary Carr

Brian Ebel

Nigel Kelly

Professor Emerita

Eileen P. Poeter

Professors Emeriti

John B. Curtis

Thomas L.T. Grose

John D. Haun

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

Joint Appointment

Stephen M. Enders

John E. McCray

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. 1.0 Semester Hr.

(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. Prerequisite: GEGN206 or equivalent. 1 hour lecture, 2 hours lab; 1 semester hour.

GEGN532. GEOLOGICAL DATA ANALYSIS. 3.0 Semester Hrs.

(I or 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. Prerequisites: Introductory statistics course (MATH323 or MATH530 equivalent). 2 hours lecture/discussion; 3 hours lab; 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.

(II) 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 geosciences. 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.
(I) Lectures, assigned readings, and discussions concerning the theory, measurement, and estimation of ground water param eters, fractured-rock flow, new or specialized methods of well hydraulics and pump tests, tracer methods. Prerequisite: 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.

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.

GEOL507. GRADUATE SEMINAR. 1.0 Semester Hr.
Equivalent with GEOL607,
(II) Recent geologic ideas and literature reviewed. Preparation and oral presentation of short papers. 1 hour seminar; 1 semester hour. Required of all geology candidates for advanced degrees during their enrollment on campus.

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. 3.0 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. 2 hours lecture, 2 hours lab; 3 semester hours.

GEOL525. TECTONOTHERMAL EVOLUTION OF THE CONTINENTS. 3.0 Semester Hrs.
(I) Evolution of the continental crust with a specific focus on processes occurring at collisional margins. Emphasis will be on the application of metamorphic processes and concepts., including integration of major, trace, and isotopic geochemistry of rocks and minerals to interpreting and understanding the tectonic and thermal evolution of the crust through space and time. Laboratory emphasizes the interpretation of metamorphic textures and assemblages within the context of geochemistry and deformation, and the application of thermodynamic principles to the understanding of the thermal history of rocks and terrains. Prerequiste: Appropriate undergraduate optical mineralogy and petrology coursework (GEOL321 and GEGN307, or equivalent). 2 hours lecture and seminar, 3 hours lab: 3 semester hours. Offered alternate years.

GEOL530. CLAY CHARACTERIZATION. 1.0 Semester Hr.
(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. Prerequisite: GEGN206 or equivalent. 1 hour lecture, 2 hours lab; 1 semester hour.

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.

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.

GEOL597. SPECIAL SUMMER COURSE. 15.0 Semester Hrs.

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.

GEOL598LA. SPECIAL TOPICS LAB. 6.0 Semester Hrs.

GEOL598LB. SPECIAL TOPICS LAB. 6.0 Semester Hrs.

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. FIELD STRATIGRAPHY. 1.0 Semester Hr.
(II) Keynote lectures and a seminar series on select topics in stratigraphy, linked to a field trip. Specific topics vary yearly depending on course participant?s interests. Seminar discussions based on reading journal papers. Field trip consists of series of projects/exercises focused on making field observations and deducing interpretations, based on multiple hypotheses. Field trip includes specific observations and recognition criteria for depositional processes and environments, as well as for regional climatic and tectonic controls. Presentation required. Prerequisite: GEOL501. 3-4 seminars, 3 hours each, over the course of the semester, and a field trip; 1 semester hour.

GEOL608. HISTORY OF GEOLOGICAL CONCEPTS. 3.0 Semester Hrs.
(II) Lectures and seminars concerning the history and philosophy of the science of geology; emphasis on the historical development of basic geologic concepts. 3 hours lecture and seminar; 3 semester hours. Required of all doctoral candidates in department. Offered alternate years.

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. Prerequisite: GEOL624 or equivalent. 4 to 6 hours lecture/ seminar/lab; 3 semester hours.

GEOL660. CARBONATE RESERVOIRS - EXPLORATION TO PRODUCTION ENGINEERING. 3.0 Semester Hrs.
(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. Prerequisite: None. 3 hours lecture and seminar; 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 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, chemistry, hydrology, and computer science, 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 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, NASA, and the National Oceanographic and Atmospheric Administration) 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 research activities of a specific faculty member 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 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 some 30 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. Further information about CWP can be obtained at http://www.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, and other agencies. More information about CGEM is available on the web at: http://geophysics.mines.edu/cgem/.

The Group for Hydrogeophysics and Porous Media 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. Website: http://www.andre-revil.com/research.html

The Planetary Geophysics Group investigates the geophysical evolution of the terrestrial planets and moons of our solar system using a combination of numerical modeling and geophysical data analysis. Research areas include planetary geodynamics, tectonics, and hydrology. More information is available at http://inside.mines.edu/~jcahanna/.

The Earthquake and Active Tectonics Group investigates earthquakes and active faulting using a combination of remote sensing, field work, dating techniques, and seismology. More information, including descriptions of recent and ongoing research, is available at http://inside.mines.edu/~enissen/.

Another research strength of the Department is the rock-physics laboratory, which conducts research in 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.

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:

GPGN/PEGNnull419	WELL LOG ANALYSIS AND FORMATION EVALUATION	3.0
GPGN/PEGNnull519	ADVANCED FORMATION EVALUATION	3.0
Two courses selected from the following:		
GEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	3.0
or GPGN439	GEOPHYSICS PROJECT DESIGN / MULTIDISCIPLINARY PETROLEUM DESIGN	
or PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	
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	

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.

Master of Science Degrees: Geophysics and Geophysical Engineering

Students may obtain a Master of Science 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 individual courses constituting the degree are determined by the student, and approved by the advisor and thesis committee, 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 Bulletin.
- 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.

Students are admitted into the Master of Science in Geophysics program. If a student would like to obtain the Master of Science in Geophysical Engineering, the student must submit a request to the Department to change to the Master of Science in Geophysical Engineering. The coursework and thesis topic 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.
- In the opinion of the Geophysics faculty, the student's dissertation topic must be appropriate for inclusion as part of an Engineering degree.

As described in the Master of Science, Thesis and Thesis Defense section of this Bulletin, all MS candidates must successfully defend their MS thesis in an open 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 Bulletin, with one exception. The Department of Geophysics requires students submit the final draft of their written thesis to their thesis committee no later than three weeks prior to the thesis defense date.

Doctor of Philosophy Degrees: Geophysics and Geophysical Engineering

We invite applications to our 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, and electrical engineering.

Students may obtain a Doctor of Philosophy 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 Bulletin.
- 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	THE ART OF SCIENCE	1.0
SYGN600	COLLEGE TEACHING	2.0
LAIS601	ACADEMIC PUBLISHING	2.0 - 3.0

- Additional courses may also be required by the student's advisor and committee to fulfill background requirements described below.

Students are admitted into the PhD in Geophysics program. If a student would like to obtain the PhD in Geophysical Engineering, the student must submit a request to the Department to change to the Doctor of Philosophy in Geophysical Engineering. The coursework and thesis topic 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.
- In the opinion of the Geophysics faculty, the student's dissertation topic must be appropriate for inclusion as part of an Engineering degree.

Students in both PhD programs are also required to participate in a practical teaching experience. This must take place within a single semester 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 no 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 bulletin, 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 Bulletin, with one exception. The Department of Geophysics requires students submit the final draft of their written thesis to their thesis committee not later than 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. The following guidelines are applied by the Department in determining the suitability of a thesis submitted as a series of written papers.

- 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 Physics
- 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 physics of the Earth
- 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 proficiency in at least one language other than English.

Professors

Terence K. Young, Professor and Department Head

Thomas L. Davis

Roelof K. Snieder, Keck Foundation Professor of Basic Exploration Science

Ilya D. Tsvankin

Associate Professors

Jeffrey Andrews-Hanna

Thomas M. Boyd, Associate Provost and Dean of Graduate Studies

Yaoguo Li

Andre Revil

Paul C. Sava, C.H. Green Chair of Exploration Geophysics

Assistant Professors

Edwin Nissen

Andrei Swidinsky

Whitney Trainor-Guitton

Professors Emeriti

Frank A. Hadsell

Alexander A. Kaufman

Gary R. Olhoeft

Phillip R. Romig, Jr.

Research Professors

Norman Bleistein, University Emeritus Professor

Dave Hale

Kenneth L. Larner, University Emeritus Professor

Research Associate Professor

Robert D. Benson

Research Assistant Professor

Richard Krahenbuhl

Adjunct Faculty

Timothy Collett

Gavin P. Hayes

Stephen J. Hill

Walter S. Lynn

Charles P. Oden

Bruce VerWest

David J. Wald

Distinguished Senior Scientists

Warren B. Hamilton

Misac N. Nabighian

Research Associate

John W. Stockwell, Jr.

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.

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.
(II) Introductory course in observational, engineering, and theoretical earthquake seismology. Topics include: seismogram interpretation, elastic plane waves and surface waves, source kinematics and constraints from seismograms, seismicity and earthquake location, magnitude and intensity estimates, seismic hazard analysis, and earthquake induced ground motions. Students interpret digital data from globally distributed seismic stations. Prerequisite: GPGN461. 3 hours lecture; 3 semester hours. Offered spring semester, odd years.

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) Presentation describing results of MS thesis research. All students must present their research at an approved public venue before the degree is granted. Every MS student registers for GPGN581 only in his/her first semester in residence and receives a grade of PRG. Thereafter, students must attend the weekly Heiland Distinguished Lecture every semester in residence. The grade of PRG is changed to a letter grade after the student?s public research presentation and thesis defense are both complete. 1 hour seminar, 1 semester hour.

GPGN597. SUMMER PROGRAMS. 12.0 Semester Hrs.

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) Presentation describing results of PhD thesis research. All students must present their research at an approved public venue before the degree is granted. Every PhD student registers for GPGN681 only in his/her first semester in residence and receives a grade of PRG. Thereafter, students must attend the weekly Heiland Distinguished Lecture every semester in residence. The grade of PRG is changed to a letter grade after the student?s public research presentation and thesis defense are both complete. 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. THE ART OF SCIENCE. 1.0 Semester Hr.
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.

Liberal Arts and International Studies

2015-2016

Degree Offered

- Master of International Political Economy of Resources

Certificates Offered

- Graduate Certificate in International Political Economy
- Graduate Certificate in Science, Technology, Engineering, and Policy

Minors Offered

- International Political Economy of Resources
- Science, Technology, Engineering, and Policy

Program Description

As the 21st century unfolds, individuals, communities, and nations face major challenges in energy, natural resources, and the environment. While these challenges demand practical ingenuity from engineers and applied scientists, solutions must also take into account social, political, economic, cultural, ethical, and global contexts. CSM students, as citizens and future professionals, confront a rapidly changing society that demands core technical skills complemented by flexible intelligence, original thought, and cultural sensitivity.

Courses in Liberal Arts and International Studies (LAIS) expand students' professional capacities by providing opportunities to explore the humanities, social sciences, and fine arts. Our curricula encourage the development of critical thinking skills that will help students make more informed choices as national and world citizens - promoting more complex understandings of justice, equality, culture, history, development, and sustainability. Students study ethical reasoning, compare and contrast different economies and cultures, and develop arguments from data and analyze globalization. LAIS courses also foster creativity by offering opportunities for self-discovery. Students conduct literary analyses, improve communication skills, play music, learn media theory, and write poetry. These experiences foster intellectual agility, personal maturity, and respect for the complexity of our world.

The Division of Liberal Arts & International Studies offers a graduate degree, the Master of International Political Economy of Resources (MIPER); two graduate certificates in International Political Economy (IPE); a graduate certificate in Science, Technology, Engineering, and Policy (STEP); and a graduate individual minor.

Combined Undergraduate/Graduate Degree Programs

Some students may earn the master's degree as part of CSM's Combined Undergraduate/Graduate programs. 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 CSM students interested in pursuing a Combined Undergraduate/Graduate program are encouraged to make an initial contact with the MIPER Director after completion of the first semester of their sophomore year for counseling on degree application procedures, admissions standards, and degree completion requirements.

See "Combined Undergraduate/Graduate Degree Programs (http://bulletin.mines.edu/graduate/programs)" elsewhere in this bulletin for further details.

Admission Requirements

The requirements for admission into LAIS 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 LAIS course work.
2. The GRE is required. Under certain circumstances, the GRE requirements can be waived. GMAT scores may be used in lieu of the GRE.
3. A TOEFL score of 580 (paper test), 237 (computer test), or 92-93 (Internet test) or higher is required for students who are non-native English speakers.

Degree Offered

- Master of International Political Economy of Resources

Requirements for a Master of International Political Economy of Resources (MIPER)

The interdisciplinary Master of International Political Economy of Resources (MIPER) aims to train the next generation of social scientists, physical scientists, and engineers so that they possess the critical skills to respond to the global challenges of natural resource management and energy policies in the 21st century. It trains them in quantitative and qualitative methodologies as well as enhancing their skills to understand, analyze, and implement complex solutions in diverse social and political settings around the world. The program is writing- and research-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 policies in the broader context of politics, economics, culture and religion.

The Master of International Political Economy of Resources (MIPER) provides students with either a thesis-based or non-thesis professional degree that requires 36 semester hours. Students in the MIPER program may choose to earn one or more minors in other departments. Please see the website https://miper.mines.edu/ for more information on specific courses associated with the degree.

Non-Thesis Option

Core Courses	15.0
Elective Courses	21.0
Total Semester Hrs	**36.0**

Thesis Option

Core Courses	15.0
Elective Courses	15.0
Research	6.0
Total Semester Hrs	**36.0**

Minors Offered

- International Political Economy of Resources
- Science, Technology, Engineering and Policy

International Political Economy of Resources (IPER) Graduate Minor

The IPER minor requires a minimum of nine (9) semester hours for Master students and twelve (12) semester hour for PhD students. Students work with a full-time LAIS faculty member to create a minor that focuses on an area of interest to the student. Courses must be at the 500- or 600-level and may include independent studies and speacial topics. The minor must be approved by the student's graduate committee and by the LAIS Division.

Science, Technology, Engineering, and Policy (STEP) Graduate Minor

The STEP graduate minor for the MS degree requires a minimum 9 semester hours of course work. The STEP graduate minor for the PhD degree requires a minimum 12 semester hours of course work. In all cases, the required course work must include LAIS586 Science and Technology Policy. Other courses may be selected from a list of recommended courses posted and regularly updated on the LAIS Science and Technology Policy Studies web site, a list which includes some courses from other academic units. Among non-LAIS courses, the MS minor is limited to one such course and the PhD minor and graduate certificate are limited to two such courses. With the approval of the LAIS STEP adviser, it is also possible to utilize a limited number of other courses from the CSM Bulletin as well as transfer courses from other institutions. For more information. please contact Dr. Jason Delborne.

Certificates Offered

- Graduate Certificate in International Political Economy
- Graduate Certificate in Science, Technology, Engineering and Policy

Graduate Certificates

The IPE Graduate Certificate program is 15 credit hour certificate and may focus on either IPE theories, methods, and models; or on specialization, such as regional development (Asia-Pacific, Latin America, Africa, Russia, Eurasia, and the Middle East), international or comparative political economy issues, and specific themes like trade, finance, the environment, gender and ethnicity. It must be approved by the MIPER Director.

The STEP graduate certificate requires a minimum 15 semester hours of course work and must include LAIS586 Science and Technology Policy. It must be approved by the STEP advisor.

Admissions requirements are the same as for the degree program. Please see the MIPER Director for more information.

Professors

Elizabeth Van Wie Davis

Juan C Lucena

Carl Mitcham

Kenneth Osgood, Director of the McBride Honors Program

Associate Professors

Hussein A. Amery

Tina L. Gianquitto, Interim Division Director

Kathleen J. Hancock

John R. Heilbrunn

Jon A. Leydens

James D. Straker

Assistant Professors

Sylvia Gaylord

Derrick Hudson, Director MIPER Program

Jessica Smith Rolston

Professors Emeriti

W. John Cieslewicz

Wilton Eckley

T. Graham Hereford

Barbara M. Olds

Eul-Soo Pang

Anton G. Pegis

Thomas Philipose, University Emeritus Professor

Arthur B. Sacks

Joseph D. Sneed

Robert E.D. Woolsey

Associate Professors Emeriti

Betty J. Cannon

Kathleen H. Ochs

Laura J. Pang

Karen B. Wiley

Teaching Professors

James V. Jesudason

Robert Klimek

Toni Lefton

Sandy Woodson, Undergraduate Advisor

Teaching Associate Professors

Jonathan H. Cullison

Paula A. Farca

Cortney E. Holles

Rose Pass

Teaching Assistant Professors

James Bishop

Olivia Burgess

Sara J. Hitt

Joseph Horan

Rachel Osgood

Seth Tucker

Courses

LAIS521. ENVIRONMENTAL PHILOSOPHY AND POLICY. 3.0 Semester Hrs.

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.

LAIS523. ADVANCED SCIENCE COMMUNICATION. 3.0 Semester Hrs.

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.

LAIS524. RHETORIC, ENERGY & PUBLIC PLCY. 3.0 Semester Hrs.

An introduction to the ways in which rhetoric shapes public policy debates that have broad social impact, particularly debates surrounding resource/energy issues. Students study and evaluate some classical but mostly contemporary rhetorical theories, as well as apply them to resource/energy-related case studies, such as sources within fossil or renewable energy. Students write a research paper and make a policy-shaping contribution to an ongoing public policy debate in fossil or renewable energy.

LAIS525. MEDIA AND THE ENVIRONMENT. 3.0 Semester Hrs.

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 communications, media studies, and cultural studies in order to understand the many ways in which the images, messages, and politics of ?nature? are constructed. Students will analyze their role as science or technology communicators and will participate in the creation of communications projects related to environmental research on campus. 3 hours seminar; 3 semester hours.

LAIS531. RELIGION AND SECURITY. 3.0 Semester Hrs.

An introduction to the central topics in religion and society. Develops an analysis of civil society in 21st century contexts and connects this analysis with leading debates about the relationship of religion and security. Creates an understanding of diverse religious traditions from the perspective of how they view security. 3 hours lecture and descission; 3 semester hours.

LAIS535. LATIN AMERICAN DEVELOPMENT. 3.0 Semester Hrs.

Explores the political economy of current and recent past development strategies, models, efforts, and issues in Latin America, one of the most dynamic regions of the world today. Development is understood to be a nonlinear, complex set of processes involving political, economic, social, cultural, and environmental factors whose ultimate goal is to improve the quality of life for individuals. The role of both the state and the market in development processes will be examined. Topics to be covered will vary as changing realities dictate but will be drawn from such subjects as inequality of income distribution; the role of education and health care; region-markets; the impact of globalization; institution-building; corporatecommunity-state interfaces; neoliberalism; privatization; democracy; and public policy formulation as it relates to development goals. 3 hours lecture and discussion; 3 semester hours.

LAIS537. ASIAN DEVELOPMENT. 3.0 Semester Hrs.

Explores the historical development of Asia Pacific from agrarian to post-industrial eras; its economic, political, and cultural transformation since World War II, contemporary security issues that both divide and unite the region; and globalization processes that encourage Asia Pacific to forge a single trading bloc. 3 hours lecture and discussion; 3 semester hours.

LAIS539. MIDDLE EAST DEVELOPMENT. 3.0 Semester Hrs.

Equivalent with LAIS439,

This course invokes economic, political, social and historical dynamics to help understand the development trajectories that the Middle East has been on in recent decades. This research-intensive graduate seminar discusses the development of Middle Eastern societies from their tribal and agrarian roots to post-industrial ones, and reflects on the pursuant contemporary security issues that both divide and unite the region, and analyzes the effects of globalization on econo.

LAIS541. AFRICAN DEVELOPMENT. 3.0 Semester Hrs.

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.

LAIS542. NATURAL RESOURCES AND WAR IN AFRICA. 3.0 Semester Hrs.

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.

LAIS545. INTERNATIONAL POLITICAL ECONOMY. 3.0 Semester Hrs.
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.

LAIS546. GLOBALIZATION. 3.0 Semester Hrs.
Assesses the historical development of international political economy as a discipline. Originally studied as the harbinger of today's political science, economics, sociology, anthropology, and history, International Political Economy is the multidisciplinary study of the relationship between states and markets. A fuller understanding will be achieved through research and data analysis as well as interpretation of case studies. Prerequisites: LAIS345 and any 400-level IPE course, or two equivalent courses. 3 hours lecture and discussion; 3 semester hours.

LAIS548. GLOBAL ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.
Examines the increasing importance of environmental policy and politics in international political economy and global international relations. Using historical analysis and interdisciplinary environmental studies perspectives, this course explores global environmental problems that have prompted an array of international and global regimes and other approaches to deal with them. It looks at the impact of environmental policy and politics on development, and the role that state and nonstate actors play, especially in North-South relations and in the pursuit of sustainability. Prerequisites: any two IPE courses at the 300-level; or one IPE course at the 400 level; or one IPE course at the 300 level and one environmental policy/issues course at the 400 level. 3 hours lecture and discussion; 3 semester hours.

LAIS550. POLITICAL RISK ASSESSMENT. 3.0 Semester Hrs.
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: LAIS 545 and IPE Minor. 3 hours seminar; 3 semester hours.

LAIS551. POL RISK ASSESS RESEARCH SEM. 1.0 Semester Hr.
When offered, this international political economy seminar must be taken concurrently with LAIS450/LAIS550, Political Risk Assessment. Its purpose is to acquaint the student with empirical research methods and sources appropriate to conducting a political risk assessment study, and to hone the students analytical abilities. Prerequisite: None. Concurrent enrollment in LAIS450/LAIS550. 1 hour seminar; 1 semester hour.

LAIS552. CORRUPTION AND DEVELOPMENT. 3.0 Semester Hrs.
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.

LAIS553. ETHNIC CONFLICT IN THE GLOBAL PERSPECTIVE. 3.0 Semester Hrs.
Studies core economic, cultural, political, and psychological variables that pertain to ethnic identity and ethnic contention, and analyzes their operation in a wide spectrum of conflict situations around the globe. Considers ethnic contention in institutionalized contexts, such as the politics of affirmative action, as well as in non-institutionalized situations, such as ethnic riots and genocide. Concludes by asking what can be done to mitigate ethnic conflict and what might be the future of ethnic group identification. 3 hours seminar; 3 semester hours.

LAIS555. INTERNATIONAL ORGANIZATIONS. 3.0 Semester Hrs.
Familiarizes students with the study of international organizations: how they are created, how they are organized and what they try to accomplish. By the end of the semester, students will be familiar with the role of international organization in the world system as well as the analytical tools used to analyze them. 3 hours lecture and discussion; 3 semester hours.

LAIS556. POWER AND POLITICS IN EURASIA. 3.0 Semester Hrs.
This seminar covers the major international economic and security issues affecting the fifteen states that once comprised the Soviet Union. The class begins with an overview of the Soviet Union and its collapse in 1991, and then focuses on the major international economic and security dilemmas facing the former Soviet states and how the US, China, European Union and other countries, as well as international organizations affect politics in the former Soviet states. Special attention will be paid to oil, natural gas, and other energy sectors in the region. 3 hours seminar; 3 semester hours.

LAIS557. INTRODUCTION TO CONFLICT MANAGEMENT. 3.0 Semester Hrs.
Introduces graduate students to the issue of international conflict management with an emphasis on conflict in resource abundant countries. Its goal is to develop analytic tools to acquire a systematic means to think about conflict management in the international political economy and to assess and react to such events. The course addresses the causes of contemporary conflicts with an initial focus on weak states, armed insurgencies, and ethnic conflict. It then turns to intra-state war as a failure of conflict management before discussing state failure, intractable conflicts, and efforts to build peace and reconstruct failed, post-conflict states. 3 hours lecture and discussion; 3 semester hours.

LAIS558. NATURAL RESOURCES AND DEVELOPMENT. 3.0 Semester Hrs.
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.

LAIS559. INTERNATIONAL INDUSTRIAL PSYCHOLOGY. 3.0 Semester Hrs.

This course has, as its primary aim, the equipping of a future consultant to deal with the cultural, socioeconomic, behavioral, psychological, ethical, and political problems in the international workplace. Specific materials covered are: Early experimentation with small group dynamics relative to economic incentive; Hawthorne experiments; experiments of Asch on perception, Analysis of case studies of work productivity in service and technological industries. Review of work of F.W. Taylor, Douglas McGregor, Blake & Mouton, and others in terms of optimum working conditions relative to wage and fringe benefits. Review ofNiccolo Machiavelli?s The Prince and the Discourses, and The Art of War by Sun Tzu with application to present times and international cultural norms. The intent of this course is to teach the survival, report writing, and presentation skills, and cultural awareness needed for success in the real international business world. The students are organized into small groups and do a case each week requiring a presentation of their case study results, and a written report of the results as well. (Textbooks: Human Side of Enterprise by Douglas McGregor, Principles of Scientific Management by F.W. Taylor, The Art of War by Sun Tzu, Up The Organization by Robert Townsend, The Prince and the Discourses of Niccolo Machiavelli, and The Managerial Grid by Blake & Mouton.) 3 hours seminar; 3 semester hours.

LAIS560. GLOBAL GEOPOLITICS. 3.0 Semester Hrs.

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.

LAIS564. QUANTITATIVE METHODS FOR THE SOCIAL SCIENCES. 3.0 Semester Hrs.

Teaches basic methods of quantitative empirical research in the social sciences. Places social science in the broader context of scientific inquiry by addressing the role of observation and hypothesis testing in the social sciences. The focus is on linear regression and group comparisions, with attention to questions of research design, internal validity, and reliability. 3 hours lecture and discussion; 3 semester hours.

LAIS565. SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.

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.

LAIS570. HISTORY OF SCIENTIFIC THOUGHT. 3.0 Semester Hrs.

This course offers a critical examination of the history of scientific thought, investigation, discovery, and controversy in a range of historical contexts. This course, which examines the transition from descriptive and speculative science to quantitative and predictive science, will help students understand the broad context of science, technology, and social relations, a key component of the MEPS program framework. 3 hours lecture and discussion; 3 semester hours.

LAIS577. ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT. 3.0 Semester Hrs.

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.

LAIS578. ENGINEERING AND SOCIAL JUSTICE. 3.0 Semester Hrs.

(II) Explores the meaning of social justice in different areas of social life and the role that engineers and engineering can play in promoting or defending social justice. Begins with students? exploration of their own social locations, alliances, and resistances to social justice through critical engagement of interdisciplinary readings that challenge engineering mindsets. Offers understandings of why and how engineering has on occasion been aligned with or divergent from specific social justice issues and causes. 3 hours seminar; 3 semester hours.

LAIS586. SCIENCE AND TECHNOLOGY POLICY. 3.0 Semester Hrs.

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.

LAIS587. ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.

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.

LAIS588. WATER POLITICS AND POLICY. 3.0 Semester Hrs.

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.

LAIS589. NUCLEAR POWER AND PUBLIC POLICY. 3.0 Semester Hrs.

A general introduction to research and practice concerning policies and practices relevant to the development and management of nuclear power. Corequisite: PHGN590 Nuclear Reactor Physics. 3 hours lecture and seminar; 3 semester hours.

LAIS590. ENERGY AND SOCIETY. 3.0 Semester Hrs.

(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.

LAIS598. 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.

LAIS599. 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.

LAIS601. ACADEMIC PUBLISHING. NaN Semester Hrs.
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.

LAIS698. 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.

LAIS699. 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.

LAIS707. 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.

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.

SYGN502. INTRODUCTION TO RESEARCH ETHICS. 1.0 Semester Hr.
A five-week course that introduces students to the various components of responsible and research practices. Topics covered move from issues related to the planning of research through the conducting of research to the dissemination of research results. The course culminates with students writing and defending their ethics statements. 1 hour lecture/lab; 1 semester hour.

Mining Engineering

Degrees Offered

- Master of Engineering (Engineer of Mines)
- Master of Science (Mining and Earth Systems Engineering)
- Doctor of Philosophy (Mining and Earth Systems Engineering)

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. 38) 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

-

Department Head

Priscilla P. Nelson

Professors

Kadri Dagdelen

Priscilla P. Nelson

M. Ugur Ozbay

Associate Professors

Mark Kuchta

Hugh B. Miller

Masami Nakagawa

Assistant Professors

Elizabeth A. Holley

Rennie Kaunda

Research Professors

Jurgen F. Brune

M. Stephen Enders

Research Associate Professor

Vilem Petr

Adjunct Faculty

John W. Grubb

Wm. Mark Hart

Raymond Henn

Paul Jones

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. TUNNELING. 3.0 Semester Hrs.

(II) Modern tunneling techniques. Emphasis on evaluation of ground conditions. Estimation of support requirements, methods of tunnel driving and boring, design systems and equipment, and safety. Prerequisite: none. 3 hours lecture; 3 semester hours.

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.

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. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours.

MNGN509. EXCAVATION PROJECT MANAGEMENT. 2.0 Semester Hrs.

Equivalent with GOGN506,

(II) Successful implementation and management of surface and underground construction projects, preparation of contract documents, project bidding and estimating, contract awarding and notice to proceed, value engineering, risk management, construction management and dispute resolution, evaluation of differing site conditions claims. Prerequisite: MNGN210, 2 hour lecture, 2 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.

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.

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.

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.

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. Prerequisites: Graduate student or senior in Mining Engineering or graduate students or seniors in other curricula. 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

2015/2016

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 CSM undergraduate students the option of a Combined Undergraduate/Graduate Program. This is an accelerated program that provides the opportunity to CSM students to have 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 bulletin. 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 bulletin.

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.

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 CSM with prior approval of the Petroleum Engineering Department at CSM.

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 will be 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 CSM. 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 Europe, 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 GPGN439	GEOPHYSICS PROJECT DESIGN / MULTIDISCIPLINARY PETROLEUM DESIGN	
or PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	
Select one of the following:		3.0
GPGN/ PEGNnull419	WELL LOG ANALYSIS AND FORMATION EVALUATION	
GPGN/ PEGNnull519	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. 12) 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. 12) 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. 12) in this bulletin and/or the Department's Graduate Student Handbook.

Professors

Hazim Abass

Ramona M. Graves, Dean, College of Earth Resource Sciences and Engineering

Hossein Kazemi, Chesebro' Distinguished Chair

Erdal Ozkan, Interim Department Head

Azra N.Tutuncu, Harry D. Campbell Chair

Yu-Shu Wu, CMG Chair

Associate Professors

Alfred W. Eustes III

Jorge H. B. Sampaio Jr.

Manika Prasad

Xiaolong Yin

Assistant Professors

Rosmer Maria Brito

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

Research Assistant Professor

Wendy Wempe

Adjunct Professor

William W. Fleckenstein

Professor Emeritus

Craig W. Van Kirk

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 LAW. 3.0 Semester Hrs.
Equivalent with ESGN502,
Designed for engineers, geoscientists, managers, consultants and citizens, this course covers the basics of environmental, energy and natural resources law. Topics include: an introduction to U.S. Environmental Law, Policy and Practice; the administrative process; enforcement and liability; a survey of U.S. laws and compliance programs addressing pollution, toxic substances, endangered species, pesticides, minerals, oil & gas, land uses and others including the National Environmental Protection Act (NEPA), Resource Conservation and Recovery Act (RCRA), Underground Storage Tanks (UST), Clean Air Act (CAA), Clean Water Act (CWA), Oil Pollution Act (OPA); Safe Drinking Water Act (SDWA); Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Toxic Substances Control Act (TSCA) and others; an introduction to international environmental law; ethics; and case studies." 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.

PEGN598LA. SPECIAL TOPICS LAB. 6.0 Semester Hrs.

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, CO_2, N_2, air, and steam) is of great interest in the light of greater demand for hydrocarbons and the need for CO_2 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.

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.

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 hydrates, renewable energy, soft materials, biomedical devices, thin-film materials, simulation and modeling. 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	MASS TRANSFER	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

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	6.0
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

CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	TRANSPORT PHENOMENA	3.0
CBEN518	REACTION KINETICS AND CATALYSIS	3.0
ELECT	Approved Electives	21.0
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

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	12.0
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 (CBEN509, CBEN516, CBEN518 and CBEN568) 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 within approximately one year of passing the Qualifying Examination. 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

John R. Dorgan

Andrew M. Herring

Carolyn A. Koh

David W.M. Marr, Department Head

J. Douglas Way

Colin A. Wolden, Weaver Distinguished Professor

David T.W. Wu, by courtesy

Associate Professors

Sumit Agarwal

Moises Carreon, Coors Developmental Chair

Keith B. Neeves

Amadeu K. Sum

Assistant Professors

Nanette Boyle, Coors Developmental Chair

Kevin J. Cash

Melissa D. Krebs

C. Mark Maupin

Ning Wu

Teaching Associate Professors

Jason C. Ganley, Assistant Department Head

Tracy Q. Gardner

Rachel M. Morrish

Cynthia L. Norrgran

Paul D. Ogg

John M. Persichetti

Judith N. Schoonmaker

Charles R. Vestal

Teaching Assistant Professor

C. Joshua Ramey

Research Associate Professor

Angel Abbud-Madrid

Research Assistant Professor

Stephanie Villano

Adjunct Faculty

John Jechura

Sarah M. Ryan

Professors Emeriti

Robert M. Baldwin

Annette L. Bunge

James F. Ely, University Professor Emeritus

John O. Golden

J. Thomas McKinnon

Ronald L. Miller

E. Dendy Sloan, Jr. , University Professor Emeritus

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,
This course stresses the application of mathematics to problems drawn from chemical engineering fundamentals such as material and energy balances, transport phenomena and kinetics. Formulation and solution of ordinary and partial differential equations arising in chemical engineering or related processes or operations are discussed. Mathematical approaches are restricted to analytical solutions or techniques for producing problems amenable to analytical solutions. Prerequisite: Undergraduate differential equations course; undergraduate chemical engineering courses covering reaction kinetics, and heat, mass and momentum transfer. 3 hours lecture discussion; 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.
(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: BIOL110, CBEN303, CHGN121, CHGN122, 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,
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 including singular and regular perturbation methods. 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 and discussion; 3 semester hours.

CBEN518. REACTION KINETICS AND CATALYSIS. 3.0 Semester Hrs.
Equivalent with CHEN518,
Homogeneous and heterogeneous rate expressions. Fundamental theories of reaction rates. Analysis of rate data and complex reaction networks. Properties of solid catalysts. Mass and heat transfer with chemical reaction. Hetero geneous non-catalytic reactions. 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. literature. Skills to be developed and discussed include oral presentations, technical writing, critical reviews, ethics, research documentation (the laboratory notebook), research funding, types of research, developing research, and problem solving, pedagogical methods, and assessment tool. solving. Students will also use state-of the-art tools to explore the literature and develop well-documented research proposals and presentations. 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.

SYGN600. COLLEGE TEACHING. 2.0 Semester Hrs.
This course is designed for graduate students planning careers in academia and focuses on principles of learning and teaching in a college setting; methods to foster and assess higher order thinking; and effective design, delivery and assessment of college courses. Prerequisite: None. 2 hours lecture; 2 semester hours.

Chemistry and Geochemistry

2015-2016

Degrees Offered

- Master of Science (Chemistry; thesis and non-thesis options)
- Doctor of Philosophy (Applied Chemistry)
- Master of Science (Geochemistry; thesis)
- Professional Masters in Environmental Geochemistry (non-thesis)
- Doctor of Philosophy (Geochemistry)

All graduate degree programs in the Department of Chemistry & Geochemistry 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 & Geochemistry offers graduate degrees in chemistry and in geochemistry. This section of the Bulletin only describes the chemistry degrees. For geochemistry degrees, please consult the Geochemistry section of the bulletin.

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 & Geochemistry at the Colorado School of Mines. Undergraduate deficiencies will be determined by faculty in the Department of Chemistry & Geochemistry 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://bulletin.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.

Professors

Mark E. Eberhart

Mark P. Jensen, Grandey University Chair in Nuclear Science & Engineering

Daniel M. Knauss

James F. Ranville

Ryan M. Richards

Bettina M. Voelker

Kim R. Williams

David T. Wu, Department Head

Associate Professors

Stephen G. Boyes

Matthew C. Posewitz

Alan S. Sellinger

Assistant Professors

Jenifer C. Braley

Svitlana Pylypenko

Brian G. Trewyn

Shubham Vyas

Yongan Yang

Teaching Professors

Renee L. Falconer

Mark R. Seger

Teaching Associate Professor

Angela Sower

Teaching Assistant Professors

Allison G. Caster

Edward A. Dempsey

Research Professors

Donald L. Macalady

Kent J. Voorhees

Research Assistant Professors

Christopher Cox

Fiona Davies

Yuan Yang

Research Faculty

Jesse Hensley

Bryan Pivovar

Robert Rundberg

Affiliated Faculty

Joseph Meyer

Professor Emeriti

Scott W. Cowley

Stephen R. Daniel

Dean W. Dickerhoof

Kenneth W. Edwards

Ronald W. Klusman

Donald Langmuir

Patrick MacCarthy

Michael J. Pavelich

E. Craig Simmons

Thomas R. Wildeman

John T. Williams

Robert D. Witters

Courses

CHGC503. INTRODUCTION TO GEOCHEMISTRY. 4.0 Semester Hrs.
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. 4 hours lecture, 4 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 equilibra. 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.

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.

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.

CHGN597. SPECIAL RESEARCH. 15.0 Semester Hrs.

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.

Metallurgical and Materials Engineering

2015-2016

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 6.0 hours of graduate research-credits listed under MTGN700.

2. Approval of all courses by the Engineering-Report Committee and the Department Head (Engineering-Report Committee consisting of 3 or more members, including the advisor and at least 2 additional members from the Metallurgical and Materials Engineering Department.)
3. Submittal and successful oral defense, before the Engineering-Report Committee, of an Engineering Report, which presents the results of a case study or an engineering 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.

The Master of Engineering Degree can be obtained as part of the combined undergraduate/graduate degree program. See "Combined Undergraduate/Graduate Degree Programs" section of the 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

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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
MTGN598	SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING	1-6
MTGN599	INDEPENDENT STUDY	1-3
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
MTGN698	SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING	1-3
MTGN699	INDEPENDENT STUDY	1-3
MTGN700	GRADUATE RESEARCH CREDIT: MASTER OF ENGINEERING	1-6
MTGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	1-15

Professors

Ivar E. Reimanis, Interim Department Head, Herman F. Coors Distinguished Professor of Ceramics

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

John G. Speer, John Henry Moore Distinguished Professor of Metallurgical and Materials Engineering

Patrick R. Taylor, George S. Ansell Distinguished Professor of Chemical Metallurgy

Chester J. Van Tyne, Associate Department Head, FIERF Professor

Associate Professors

Kip O. Findley

Brian Gorman

Jeffrey C. King

Steven W. Thompson

Assistant Professors

Geoff L. Brennecka

Emmanuel De Moor

Corinne E. Packard

Vladan Stevanovic

Zhenzhen Yu

Teaching Associate Professors

Gerald Bourne

John P. Chandler

Research Professors

Richard K. Ahrenkiel

Ivan Cornejo

Hongjun Liang

Stephen Midson

William Sproul

William (Grover) Coors

Robert Field

Terry Lowe

D. (Erik) Spiller

James C. Williams

Research Associate Professors

Robert Cryderman

Carole Graas

Jianhua Tong

Edgar Vidal

Research Assistant Professors

David Diercks

Judith C. Gomez

Jianliang Lin

Svitlana Pylypenko

Professors Emeriti

George S. Ansell, President Emeritus

W. Rex Bull, Professor Emeritus

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

John J. Moore, Professor Emeritus

David L. Olson, University Professor Emeritus

Dennis W. Readey, University Professor Emeritus

Associate Professors Emeriti

Gerald L. DePoorter

Robert H. Frost

Physics

2015-2016

Degrees Offered

- Master of Science (Applied Physics)
- Doctor of Philosophy (Applied Physics)

Program Description

The Physics Department at CSM offers a full program of instruction and research leading to the M.S. 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 $6.5M/year. Research in the Department is organized under three primary themes: subatomic physics, condensed matter physics, and applied optics. With 23 faculty, 83 graduate students, and 262 undergraduate physics majors, the Physics Department at CSM 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 Applied Physics 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.

Doctorate 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, Applied 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, 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

Frank V. Kowalski

Mark T. Lusk

Frederic Sarazin

John A. Scales

Jeff A. Squier, Department Head

P. Craig Taylor

Associate Professors

Timothy R. Ohno

Lawrence R. Wiencke

David M. Wood

Assistant Professors

Kyle G. Leach

Susanta K. Sarkar

Eric S. Toberer

Zhigang Wu

Jeramy D. Zimmerman

Teaching Professors

Alex T. Flournoy

Patrick B. Kohl

H. Vincent Kuo

Todd G. Ruskell

Charles A. Stone

Matt Young

Teaching Associate Professor

Kristine E. Callan

Research Professors

Mark W. Coffey

Jonathan L. Mace

Zeev Shayer

Research Associate Professors

Joseph D. Beach

James E. Bernard

Research Assistant Professor

P. David Flammer

Professors Emeriti

F. Edward Cecil

Thomas E. Furtak

James A. McNeil

Don L. Williamson

Associate Professors Emeriti

William B. Law

Arthur Y. Sakakura

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.

PHGN597. SUMMER PROGRAMS. 6.0 Semester Hrs.

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.

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	4.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
Master of Science (Geochemistry) students select two of the following:		3-4
CHGN503	ADV PHYSICAL CHEMISTRY I	
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	
GEOL512	MINERALOGY AND CRYSTAL CHEMISTRY	
CHGC514	GEOCHEMISTRY THERMODYNAMICS AND KINETICS	

GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	

In addition, all students must complete a 1-2 hour laboratory course selected from several available. 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. At least 24 hours must be research credit and at least 18 hours must be course work. Up to 24 hours of course credit may be transferred from previous graduate-level work upon approval of the thesis committee. Research credits may not be transferred. Students who enter the Doctor of Philosophy (Geochemistry degree track) program with a thesis-based Master of Science degree from another institution may transfer up to 36 semester hours, upon approval of the thesis committee, in recognition of the course work and research completed for that degree.

Doctor of Philosophy (Geochemistry degree track) students must take:

CHGC503	INTRODUCTION TO GEOCHEMISTRY	4.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
CHGC514	GEOCHEMISTRY THERMODYNAMICS AND KINETICS	3.0
Laboratory course		1.0
Select two of the following:		3-4
CHGN503	ADV PHYSICAL CHEMISTRY I	
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	
GEOL512	MINERALOGY AND CRYSTAL CHEMISTRY	
GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	

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) and Doctor of Philosophy (Geochemistry degree track) students resident in the Department of Chemistry and Geochemistry or the Department of Geology and Geological Engineering shall adhere to the seminar rules and requirements of the department of residence.

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	4.0
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 ((New class) Adv Geoenvironmental Anal)	3.0
(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	4.0
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
Total Semester Hrs		**10.0**

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	ADVANCED GROUNDWATER ENGINEERING	3.0
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
GEOL530	CLAY CHARACTERIZATION	1.0
GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	3.0

Laboratory courses:

(New course) Adv Geoenvironmental Anal		3.0
GEOL530	CLAY CHARACTERIZATION	1.0

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	4.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
CHGC505	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0
CHGC506	WATER ANALYSIS LABORATORY	2.0
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
CHGC511	GEOCHEMISTRY OF IGNEOUS ROCKS	3.0
CHGC527	ORGANIC GEOCHEMISTRY OF FOSSIL FUELS AND ORE DEPOSITS	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
CHGC555	ENVIRONMENTAL ORGANIC CHEMISTRY	3.0
CHGC563	ENVIRONMENTAL MICROBIOLOGY	2.0
CHGC564	BIOGEOCHEMISTRY AND GEOMICROBIOLOGY	3.0
CHGC598	SPECIAL TOPICS	1-6
CHGC698	SPECIAL TOPICS	1-6

Professors

Wendy J. Harrison, Geology and Geological Engineering

Murray W. Hitzman, Charles F. Fogarty Professor of Economic Geology

John McCray, Civil and Environmental Engineering

James F. Ranville, Chemistry and Geochemistrty

John R. Spear, Civil and Environmental Engineering

Bettina M. Voelker, Chemistry and Geochemistry

Richard F. Wendlandt, Geology and Geological Engineering

Associate Professors

Linda A. Figueroa, Civil and Environmental Engineering

John D. Humphrey , Geology and Geological Engineering

Thomas Monecke, Geology and Geological Engineering

Jonathan O. Sharp, Civil and Environmental Engineering

Assistant Professors

Alexander Gysi, Geology and Geological Engineering

Christopher P. Higgins, Civil and Environmental 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

2015-2016

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. Students may elect to follow the Science or the Engineering Track.

HSE requires a core study of 4 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 a project report, 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. In the Combined Degree Program as many as six credit hours may be counted towards the B.S. and M.S. non-thesis degree requirements. 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) Bulletins 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. 19).

Currently, students will apply to the hydrology program through the Graduate School and be assigned to the HSE participating department or division of the student's HSE advisor. Participating units include: Chemistry and Geochemistry, Civil & Environmental Engineering (CEE), Geology and Geological Engineering (GE), Geophysical Engineering, Mining Engineering (ME), 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 faculty.

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 all committees one at-large member must be from a department outside the student's home department and HSE.

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
- fluid mechanics, one semester 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. 38) 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 CEEN583	SURFACE WATER QUALITY MODELING	
Total Semester Hrs		**12.0**

Starting Fall 2015 a two credit hour Fluid Mechanics for Hydrology is required for the HSE graduate degrees. 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	ADVANCED GROUNDWATER ENGINEERING	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
LAIS588	WATER POLITICS AND POLICY	3.0

Directors

Terri Hogue, HSE Director, Civil & Environmental Engineering

Kamini Singha, HSE Associate Director, Geology & Geological Engineering

Department of Chemistry and Geochemistry

James Ranville, Professor

Bettina Voelker, Professor

Department of Civil & Environmental Engineering

Tzahi Y. Cath, Associate Professor

Linda Figueroa, Associate Professor

Marte Gutierrez, Professor & James R. Paden Distinguished Professor

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, Associate Professor

John Humphrey, Associate Professor

Reed Maxwell, Professor

Eileen Poeter, Professor Emerita

Paul Santi, Professor & Department Head Geology & Geological Engineering

Kamini Singha, Associate Professor

Alexis Sitchler, Assistant Professor

Department of Geophysics

Jeff Andrews-Hannah, Assistant Professor

David Hale, Professor

Yaoguo Li, Associate Professor

Division of Liberal Arts & International Studies

Hussein Amery, Professor

Department of Petroleum Engineering

Yu-Shu Wu, 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

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/ MATHnull406	ALGORITHMS	3.0
MEGN502	ADVANCED ENGINEERING ANALYSIS	4.0
MATH530	STATISTICAL METHODS I	3.0
EBGN555	LINEAR PROGRAMMING	3.0
Total Semester Hrs		**13.0**

Area of Specialization Courses

Select Four of the Following:		12.0
EBGN528	INDUSTRIAL SYSTEMS SIMULATION	
or MATH542	SIMULATION	
or CSCI542	SIMULATION	
MTGNnull450/ 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 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 Departments of Chemistry and Geochemistry, Metallurgical and Materials Engineering, Physics, and Chemical and Biological Engineering jointly administer the interdisciplinary materials science program. This interdisciplinary degree program coexists along side strong disciplinary programs, in Chemistry, Chemical and Biochemical Engineering, Mechanical Engineering, Metallurgical and Materials Engineering, and Physics. 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.

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.

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

Program Requirements

Each of the three degree programs 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.

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 Fall semester 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 a student receives a grade of less than B- in a class, the student may request an additional final examination be given during the mid-term break of

the following spring semester. If the result of this examination is a B- or better, the student will be allowed to take the qualifying examination. The grade originally obtained in the course will not be changed as a result. 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

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 students are expected to successfully complete the qualifying examination within three semesters 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 subsequent fall 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.

Thesis Proposal – A student's thesis committee administers a Thesis Proposal defense. The 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 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 Defense of Thesis examination before the Thesis Committee.

MLGN500	PROCESSING, MICROSTRUCTURE, AND PROPERTIES OF MATERIALS	3.0
MLGN501	STRUCTURE OF MATERIALS	3.0
MLGN502	SOLID STATE PHYSICS	3.0
MLGN503	CHEMICAL BONDING IN MATERIALS	3.0
MLGN504	SOLID STATE THERMODYNAMICS	3.0
MLGN505	MECHANICAL PROPERTIES OF MATERIALS	3.0
MLGN506	TRANSPORT IN SOLIDS	3.0
MLGN509	SOLID STATE CHEMISTRY	3.0
MLGN510	SURFACE CHEMISTRY	3.0
MLGN511	KINETIC CONCERNS IN MATERIALS PROCESSING I	3.0
MLGN512	CERAMIC ENGINEERING	3.0
MLGN513	PROBLEM SOLVING IN MATERIALS SCIENCE	3.0
MLGN515	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS	3.0
MLGN516	PROPERTIES OF CERAMICS	3.0

MLGN517	SOLID MECHANICS OF MATERIALS	3.0
MLGN518	PHASE EQUILIBRIA IN CERAMICS SYSTEMS	3.0
MLGN519	NON-CRYSTALLINE MATERIALS	3.0
MLGN521	KINETIC CONCERNS IN MATERIAL PROCESSING II	3.0
MLGN523	APPLIED SURFACE AND SOLUTION CHEMISTRY	3.0
MLGN526	GEL SCIENCE AND TECHNOLOGY	3.0
MLGN530	INTRODUCTION TO POLYMER SCIENCE	3.0
MLGN531	POLYMER ENGINEERING AND TECHNOLOGY	3.0
MLGN535	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
MLGN536	ADVANCED POLYMER SYNTHESIS	3.0
MLGN544	PROCESSING OF CERAMICS	3.0
MLGN550	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS	3.0
MLGN552	INORGANIC MATRIX COMPOSITES	3.0
MLGN555	POLYMER AND COMPLEX FLUIDS COLLOQUIUM	1.0
MLGN561	TRANSPORT PHENOMENA IN MATERIALS PROCESSING	3.0
MLGN563	POLYMER ENGINEERING: STRUCTURE, PROPERTIES AND PROCESSING	3.0
MLGN565	MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES	3.0
MLGN569	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MLGN570	BIOCOMPATIBILITY OF MATERIALS	3.0
MLGN572	BIOMATERIALS	3.0
MLGN583	PRINCIPLES AND APPLICATIONS OF SURFACE ANALYSIS TECHNIQUES	3.0
MLGN589	MATERIALS THERMODYNAMICS	3.0
MLGN591	MATERIALS THERMODYNAMICS	3.0
MLGN592	ADVANCED MATERIALS KINETICS AND TRANSPORT	3.0
MLGN593	BONDING, STRUCTURE, AND CRYSTALLOGRAPHY	3.0
MLGN607	CONDENSED MATTER	3.0
MLGN625	MOLECULAR SIMULATION METHODS	3.0
MLGN634	ADVANCED TOPICS IN THERMODYNAMICS	3.0
MLGN635	POLYMER REACTION ENGINEERING	3.0
MLGN648	CONDENSED MATTER II	3.0
MLGN673	STRUCTURE AND PROPERTIES OF POLYMERS	3.0
MLGN696	VAPOR DEPOSITION PROCESSES	3.0
MLGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	1-15

Professors

Colin Wolden , Department of Chemical Engineering, Weaver Distinguished Professor

Stephen Liu , Department of Metallurgical and Materials Engineering, American Bureau of Shipping Endowed Chair of Metallurgical and Materials Engineering

John R. Dorgan, Department of Chemical and Biological Engineering

Mark Eberhart, Department of Chemistry and Geochemistry

Thomas E. Furtak, Department of Physics

Michael J. Kaufman, Department of Metallurgical and Materials Engineering, Dean of CASE

Daniel M. Knauss, Department of Chemistry and Geochemistry

Ryan P. O'Hayre, Department of Metallurgical and Materials Engineering

Ivar E. Reimanis, Department of Metallurgical and Materials Engineering, Herman F. Coors Distinguished Professor of Ceramic Engineering

P. Craig Taylor, Department of Physics

Chester J. Van Tyne, Department of Metallurgical and Materials Engineering, FIERF Professor and Associate Department Head

Associate Professors

John R. Berger, Department of Mechanical Engineering

Stephen G. Boyes, Department of Chemistry and Geochemistry

Cristian V. Ciobanu, Department of Mechanical Engineering

Brian P. Gorman, Department of Metallurgical and Materials Engineering

Timothy R. Ohno, Department of Physics

Ryan Richards, Department of Chemistry and Geochemistry, Materials Science Program Interim Director

Neal Sullivan, Department of Mechanical Engineering

Assistant Professors

Geoff L. Brennecka, Department of Metallurgical and Materials Engineering

Honjun Liang, Department of Metallurgical and Materials Engineering

Corinne E. Packard, Department of Metallurgical and Materials Engineering

Eric Toberer, Department of Physics

Zhigang Wu, Department of Physics

Yongan Yang, Department of Chemistry and Geochemistry

Professors Emeriti

John Moore, Department of Metallurgical and Materials Engineering

Denis W. Readey, Department of Metallurgical and Materials Engineering, University Professor-Emeritus

Teaching Associate Professors

Gerald Bourne, Department of Metallurgical and Materials Engineering

John Chandler, 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 Professors

James E. Bernard, Department of Physics

Jianhua Tong, Department of Metallurgical and Materials Engineering

Research Assistant Professors

David Diercks, Department of Metallurgical and Materials Engineering

Jianliang Lin, Department of Metallurgical and Materials Engineering

Nuclear Engineering

2015-2016

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 Applied Mathematics and Statistics, the Department of Chemistry and Geochemistry, the Department of Civil and Environmental Engineering, the Department of Liberal Arts and International Studies, the Department of Mechanical Engineering, the Department of Metallurgical and Materials Engineering, and the Department of Physics. 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 CSM's 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 21 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	9.0
Additional elective courses	12.0
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 modern physics and 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
LAIS589	NUCLEAR POWER AND PUBLIC POLICY	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
NUGN598	NUCLEAR FUEL CYCLE	

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, Liberal Arts and International Studies, 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
LAIS589 or CEEN558	NUCLEAR POWER AND PUBLIC POLICY 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**

NUGN505	NUCLEAR SCIENCE AND ENGINEERING SEMINAR	1.0
NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
NUGN535	INTRODUCTION TO HEALTH PHYSICS	3.0
NUGN580	NUCLEAR REACTOR LABORATORY	3.0
NUGN585	NUCLEAR REACTOR DESIGN I	2.0
NUGN586	NUCLEAR REACTOR DESIGN II	2.0
NUGN598	SPECIAL TOPICS	1-6
NUGN698	SPECIAL TOPICS	6.0
NUGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	1-12

Program Director

Mark Jensen, Jerry and Tina Grandey University Chair in Nuclear Science and Engineering, Department of Chemistry and Geochemistry

College of Engineering and Computational Sciences

Kevin Moore, Professor and Dean

Department of Applied Math and Statistics

Cory Ahrens, Assistant Professor

Department of Chemistry

James Ranville, Associate Professor

Jenifer Braley, Assistant Professor

Department of Civil and Environmental Engineering

Linda Figueroa, Associate Professor, Nuclear Science and Engineering Center Management Team Co-Chair

Department of Mechanical Engineering

Robert Kee, Professor

Douglas Van Bossuyt, Assistant Professor

Department of Metallurgical and Materials Engineering

Corby Anderson, Professor

Gerard Martins, Professor

Brajendra Mishra, Professor

David Olson, Professor

Ivar Reimanis, Professor

Patrick Taylor, Professor

Brian Gorman, Associate Professor

Jeffrey King, Associate Professor

Edgar Vidal, Research Associate Professor

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

Jim McNeil, Professor Emeritus

Edward Cecil, University Professor Emeritus

Zeev Shayer, Research Professor

Underground Construction & Tunneling

2015-2016

Degrees Offered

- Master of Science (Underground Construction & Tunneling), Thesis
- Master of Science (Underground Construction & Tunneling), Non-Thesis
- Doctor of Philosophy (Underground Construction & Tunneling)

Program Description

Underground Construction and Tunneling (UC&T) is an interdisciplinary field primarily involving civil engineering, geological engineering and mining engineering, and secondarily involving mechanical engineering, electrical engineering, geophysics, geology and others. UC&T deals with the design, construction, rehabilitation and management of underground space including caverns, shafts and tunnels for commercial, transportation, water and wastewater use. UC&T 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 UC&T will gain a strong and interdisciplinary foundation in these topics.

The graduate degree program in UC&T is offered jointly by the Departments of Civil & Environmental Engineering (CEE), Geology & Geological Engineering (GEGN), and Mining Engineering (MN). UC&T 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 UC&T 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 UC&T faculty advisor and doctoral committee, which culminates in a significant scholarly contribution to a specialized field in UC&T. 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 Bulletin.

Program Requirements

M.S. Non-Thesis Option:

Coursework - 27.0 credit hours

Independent Study* - 3.0 credit hours

UC&T 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 UC&T 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 UC&T 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

UC&T 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 UC&T 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

UC&T 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 UC&T. 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 UC&T 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 UC&T faculty member and industry partner culminating with a written report and presentation.

Required Coursework

The following 21 credit hours are required for the M.S. (thesis and non-thesis) and Ph.D. degrees.

GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
MNGN504	TUNNELING	3.0
MNGN508	ADVANCED ROCK MECHANICS	3.0
MNGN509	EXCAVATION PROJECT MANAGEMENT	2.0
CEEN512	SOIL BEHAVIOR	3.0
CEEN520	EARTH RETAINING STRUCTURES / SUPPORT OF EXCAVATIONS	3.0
CEEN523	ANALYSIS AND DESIGN OF TUNNELS IN SOFT GROUND	3.0

All M.S. and Ph.D. students are required to attend the UC&T 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 (CEEN 599, GEGN 599, or MNGN 599). 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.

Course List

CEEN415 (p. 168)	FOUNDATIONS	3.0
CEEN506 (p. 168)	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN510 (p. 168)	ADVANCED SOIL MECHANICS	3.0
CEEN541 (p. 168)	DESIGN OF REINFORCED CONCRETE STRUCTURES	3.0
CEEN599 (p. 168)	INDEPENDENT STUDY	1-6
GEGN466 (p. 168)	GROUNDWATER ENGINEERING	3.0
GEGN573 (p. 168)	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN581 (p. 168)	ANALYTICAL HYDROLOGY	3.0
GEGN672 (p. 168)	ADVANCED GEOTECHNICS	3.0
GEGN673 (p. 168)	ADVANCED GEOLOGICAL ENGINEERING DESIGN	3.0
GEGN599 (p. 168)	INDEPENDENT STUDY	1-6
MNGN424 (p. 168)	MINE VENTILATION	3.0
MNGN506 (p. 168)	DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS	3.0
MNGN507 (p. 168)	ADVANCED DRILLING AND BLASTING	3.0
MNGN524 (p. 168)	ADVANCED MINE VENTILATION	3.0
MNGN590 (p. 168)	MECHANICAL EXCAVATION IN MINING	3.0
MNGN599 (p. 168)	INDEPENDENT STUDY	1-6

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 UC&T faculty member. For Ph.D. students, at least two committee members must be members of the UC&T faculty.

Prerequisites

Students will enter the UC&T programs with a variety of backgrounds. Because the UC&T degrees are engineering degrees, the required prerequisite courses for the UC&T 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 UC&T 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 UC&T faculty for guidance in this matter.

Director

Michael Mooney, Grewcock Distinguished Chair & Professor

Department of Civil & Environmental Engineering

Marte Gutierrez, J.R. Paden Distinguished Chair & Professor

Reza Hedayat, Assistant Professor

Panos Kiousis, Associate Professor

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Jerry Higgins, Associate Professor

Paul Santi, Dept Head & 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

Ugur Ozbay, Professor

Policies and Procedures

2015-2016

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 Associate Dean of Students located in the Student Center, Suite 172.

For emphasis, the following policies are included in this section:

- Student Honor Code
- Policy on Academic Integrity/Misconduct
- Policy Prohibiting Sexual Harassment (includes sexual assault and sexual violence)
- Unlawful Discrimination Policy and Complaint Procedure (currently under revision)
- Electronic Communications (E-mail) Policy
- Student Complaint Process
- Access to Student Records
- Posthumous Degree Awards
- Equal Opportunity, Equal Access, and Affirmative Action

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 Associate 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 Associate 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 Associate 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 Associate 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 Associate 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 Associate 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 Associate Dean of Students. The information is then provided to the faculty member concerned.

4.0 APPEAL PROCESS FOR STUDENT ACADEMIC MISCONDUCT

The academic misconduct appeal process is under revision. For the most up-to-date version of this procedure, please see the student section of the policy website (https://inside.mines.edu/POGO-Policies-Governance).

Policy Prohibiting Sexual Harassment*

*Note: This policy is inclusive of all forms of sexual harassment, including sexual assault and sexual violence.

1.0 STATEMENT OF AUTHORITY AND PURPOSE

This policy is promulgated pursuant to the authority conferred by §23-41-104(1), C.R.S., and Title IX of the Education Amendments of 1972 (Title IX), 20 U.S.C. §§ 1681 *et seq.*, and its implementing regulations, 34 C.F.R. Part 106; Title IV of the Civil Rights Act of 1964 (42 U.S.C. § 2000c).Its purpose is to set forth a policy statement from the Board of Trustees concerning sexual harassment at the Colorado School of Mines ("Mines" or "the School").This policy shall supersede any Mines' policy that is in conflict herewith.

2.0 SEXUAL HARASSMENT POLICY

2.1 Policy Statement

The Mines Board of Trustees wishes to foster an environment for the Mines' campus community that is free from all forms of sexual harassment. Accordingly, the School will not tolerate any forms of sexual harassment and will take all necessary measures to deter such misconduct, including but not limited to preventive educational programs, thorough investigation of sexual harassment complaints, and discipline of policy violators with appropriate sanctions. Retaliation in any form against an individual for reporting sexual harassment or cooperating in a sexual harassment investigation is strictly prohibited. Such retaliation shall be dealt with as a separate instance of sexual harassment. Complaints of sexual harassment will be handled in accordance with the administrative procedures that accompany this policy.

2.2 Definition of Sexual Harassment

Sexual harassment shall, without regard to the gender of the Complainant or Respondent,consist 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 by an individual is used as the basis for employment or educational decisions affecting the individual; 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.

Sexual violence and sexual assault are forms of sexual harassment. Sexual harassment shall also be defined to include retaliation against an individual for reporting sexual harassment or cooperating in a sexual harassment investigation.

2.3 Sanctions for Sexual Harassment

Appropriate sanctions may be imposed upon an employee or student who has sexually harassed another. The sanctions may include, but are not limited to one or more of the following: oral reprimand and warning; written reprimand and warning; student probation; suspension or expulsion; monetary fine; attendance at a sexual harassment prevention seminar; suspension without pay; or termination of employment or appointment.

3.0 IMPLEMENTATION

The Mines Board of Trustees authorizes and directs the President or President's delegates to develop, administer, and maintain the appropriate administrative policies, procedures, and guidelines to implement this policy.

Title IX Coordinator:

Karin Ranta-Curran, Assistant Director of HR for EEO and Equity
Guggenheim Hall, Room 110
Golden, CO 80401
(Telephone: 303.384.2558)
(E-Mail: krcurran@mines.edu)

Contact for Complaints about Employee or Third-Party Behavior:

Mike Dougherty, Associate Vice President for Human Resources
Guggenheim Hall, Room 110
Golden, CO 80401
(Telephone: 303.273.3250)

Contact for Complaints about Student Behavior:

Derek Morgan, Associate Dean of Students
Student Center, Room 175
1200 6th Street
Golden, CO 80401
(Telephone: 303.273.3288)

Related Administrative Policies, Procedures, Resources:

For Complaints about Employee or Third-Party Behavior:

- Sexual Harassment Complaint, Investigation and Resolution Procedure for Complaints Involving Employees or Third Parties
- Sexual Harassment Complaint Investigation Authorization Form

For Complaints about Student Behavior:

- Sexual Harassment Complaint, Investigation, Resolution and Adjudication Procedure for Complaints about Student Behavior
- Procedures/Resources for Survivors of Sexual Assault or Other Sexual Violence
- Anonymous Sexual Violence Reporting Form

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.

Unlawful Discrimination Policy and Complaint Procedure

I. STATEMENT OF AUTHORITY 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 CSM. This policy shall supersede any previously promulgated CSM policy that is in conflict herewith.

II. UNLAWFUL DISCRIMINATION POLICY

Attendance and employment at CSM 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, promotion, compensation, transfers, reductions in force, terminations, re-employment, professional development, or conditions of employment shall be permitted. The remainder of this policy shall contain a complaint procedure outlining a method for reporting alleged violations of this policy and a review mechanism for the impartial determination of the merits of complaints alleging unlawful discrimination.

As of June 2011, this policy is under revision. **For a complete policy statement** *please see the policy website* (https://inside.mines.edu/POGO-Policies-Governance). *Promulgated by the CSM Board of Trustees on March 13, 1992. Amended by the CSM Board of Trustees on June 10, 1999. Amended by the CSM Board of Trustees on June 22, 2000.*

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.

3.0 PROCEDURES

1. All students will be given an EKey, which is an activation code that offers access to electronic resources at Mines. With their EKey, students must activate their assigned Mines email address.
2. Once their email address is activated, students are expected to check their Mines email inbox on a frequent and consistent basis and have the responsibility to recognize that certain communications from the university may be timecritical. As such, students also are responsible

for responding in a timely manner to official communications from the university when a response is requested.

3. The policy does not prevent students from using a personal email address for university-related communications and purposes. If a student chooses to use a personal email address as his or her address of choice for receiving university-related communications, he or she must forward email from the Mines assigned email address to the personal email address. However, if a student chooses to forward communications to a personal email address, she or he must be aware that Mines personnel may not be able to assist in resolving technical difficulties with personal email accounts. Furthermore, forwarding communications to a personal email address does not absolve a student from the responsibilities associated with communication sent to his or her official Mines email address. Please note: If a student changes his or her official Mines email address to a personal address, it will be changed back to the Mines assigned email address. Students have the option to forward their Mines email to a personal address to avoid this problem. Should a student choose the forwarding option, he or she must ensure that SPAM filters will not block email coming from the mines.edu address.
4. Nothing in these 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.

Responsible Parties

Questions about this policy may be directed as follows:

Registrar's Office Phone: 303-273-3200 or
E-mail: registrar@mines.edu

Computing, Communications & Information Technologies (CCIT)
Phone: 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 303-273-3231. If the issue is related to discrimination or sexual harassment, there are specific procedures that will be followed (these are noted and linked in this section). Regardless, 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 is

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, and academic honors. 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.

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 Ph.D. 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 Ph.D., 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 Bulletin as well as the on the policy website (https://inside.mines.edu/POGO-Policies-Governance). Colorado School of Mines has instituted an affirmative action plan, which is available for perusal in numerous CSM offices including the Library, the Dean of Students' Office, and the Office of Human Resources.

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