

UNDERGRADUATE BULLETIN



Colorado School of Mines

2006–2007



*Colorado
School of Mines*

*2006–2007
Undergraduate Bulletin*

To CSM Students:

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

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Academic Calendar

Fall Semester 2006

Confirmation deadline	Aug. 21, Monday
Faculty Conference	Aug. 21, Monday
Classes start (1)	Aug. 22, Tuesday
Graduate Students—last day to register without late fee	Aug. 27, Sunday
Labor Day (Classes held)	Sept. 4, Monday
Last day to register, add or drop courses without a “W” (Census Day)	Sept. 6, Wednesday
Fall Break Day	Oct. 16, Monday
Midterm grades due	Oct. 16, Monday
Last day to withdraw from a course—Continuing students	Oct. 31, Tuesday
Priority Registration Spring Semester	Nov. 13-17, Monday–Friday
Thanksgiving Break	Nov. 23–Nov. 26, Thursday–Sunday
Last day to withdraw from a course—New students	Dec. 1, Friday
Classes end	Dec. 7, Thursday
Dead Day	Dec. 8, Friday
Graduating students’ lowest possible grades due	Dec. 12, Tuesday
Final exams	Dec. 9, 11-14, Saturday, Monday–Thursday
Semester ends	Dec. 15, Friday
Midyear Degree Convocation	Dec. 15, Friday
Final grades due	Dec. 18, Monday
Winter Recess	Dec. 16–Jan. 9, Saturday–Tuesday

Spring Semester 2007

Confirmation deadline	Jan. 9, Tuesday
Classes start (1)	Jan. 10, Wednesday
Grad Students—last day to register without late fee	Jan. 14, Sunday
Last day to register, add or drop courses without a “W” (Census Day)	Jan. 25, Thursday
Midterms grades due	March 5, Monday
Spring Break	March 10-18, Saturday–Sunday
Last day to withdraw from a course	March 28, Tuesday
All students except new students & 2nd semester freshmen	
E-Days	April 5-7, Thursday–Saturday
Priority Registration, Field, Summer and Fall Term	April 9-13, Monday–Friday
Last day to withdraw from a course—new students & 2nd semester freshmen	April 27, Friday
Classes end	May 3, Thursday
Dead Day	May 4, Friday
Graduating students’ lower possible grades due	May 8, Tuesday
Final exams	May 5, May 6-10 Saturday, Monday–Thursday
Semester ends	May 11, Friday
Commencement	May 11, Friday
Final grades due	May 14, Monday

Field/Summer Sessions 2007

First Field Term First Day of Class, Registration (1)	May 14, Monday
Last day to register, add or drop courses without a “W”—Field Term (Census Day)	May 18, Friday
Memorial Day (Holiday—No classes held)	May 28, Monday
Last day to withdraw from First Field Term	June 8, Friday
First Field Term ends	June 22, Friday
Field Term grades due	June 25, Monday
Summer School First Day of Class, Registration (1)	June 18, Monday
Last day to register, add or drop courses without a “W”—Summer School (Census Day)	June 26, Tuesday
Independence Day (Holiday—No classes held)	July 4, Wednesday
Second Field Term begins	July 9, Monday
Last day to register, add or drop courses without a “W”—Second Field Term	July 13, Friday
Last day to withdraw from Summer School	July 13, Friday
Last day to withdraw from Second Field Term	August 3, Friday
Summer School ends	Aug. 10, Friday
Summer School grades due	Aug. 13, Monday
Second Field Term ends	Aug. 17, Friday
Second Field Term grades due	Aug. 20, Monday

(1) Petition for changes in tuition classification due in the Registrar’s office for this term.

Section 1 – Welcome

Mission and Goals

Colorado School of Mines is a public research university devoted to engineering and applied science related to resources. It is one of the leading institutions in the nation and the world in these areas. It has the highest admission standards of any university in Colorado and among the highest of any public university in the U.S. CSM has dedicated itself to responsible stewardship of the earth and its resources. It is one of a very few institutions in the world having broad expertise in resource exploration, extraction, production and utilization which can be brought to bear on the world's pressing resource-related environmental problems. As such, it occupies a unique position among the world's institutions of higher education.

The school's role and mission has remained constant and is written in the Colorado statutes 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)*

Throughout the school's history, the translation of its mission into educational programs has been influenced by the needs of society. Those needs are now focused more clearly than ever before. We believe that the world faces a crisis in balancing resource availability with environmental protection and that CSM and its programs are central to the solution to that crisis. Therefore the school's mission is elaborated upon as follows:

Colorado School of Mines is dedicated to educating students and professionals in the applied sciences, engineering, and associated fields related to

- ◆ *the discovery and recovery of the Earth's resources,*
- ◆ *their conversion to materials and energy,*
- ◆ *their utilization in advanced processes and products, and*
- ◆ *the economic and social systems necessary to ensure their prudent and provident use in a sustainable global society.*

This mission will be achieved by the creation, integration, and exchange of knowledge in engineering, the natural sciences, the social sciences, the humanities, business and their union to create processes and products to enhance the quality of life of the world's inhabitants.

The Colorado School of Mines is consequently committed to serving the people of Colorado, the nation, and the global community by promoting stewardship of the Earth upon which all life and development depend. (Colorado School of Mines Board of Trustees, 2000)

The Academic Environment

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

CSM offers the bachelor of science degree in Chemical Engineering, Chemistry, Economics, Engineering, Engineering Physics, Geological Engineering, Geophysical Engineering, Mathematical and Computer Sciences, Metallurgical and Material Engineering, Mining Engineering, and Petroleum Engineering. A pervasive institutional goal for all of these programs is articulated in the *Profile of the Colorado School of Mines Graduate*:

- ◆ All CSM graduates must have depth in an area of specialization, enhanced by hands-on experiential learning, and breadth in allied fields. They must have the knowledge and skills to be able to recognize, define and solve problems by applying sound scientific and engineering principles. These attributes uniquely distinguish our graduates to better function in increasingly competitive and diverse technical professional environments.
- ◆ Graduates must have the skills to communicate information, concepts and ideas effectively orally, in writing, and graphically. They must be skilled in the retrieval, interpretation and development of technical information by various means, including the use of computer-aided techniques.

- ◆ Graduates should have the flexibility to adjust to the ever changing professional environment and appreciate diverse approaches to understanding and solving society's problems. They should have the creativity, resourcefulness, receptivity and breadth of interests to think critically about a wide range of cross-disciplinary issues. They should be prepared to assume leadership roles and possess the skills and attitudes which promote teamwork and cooperation and to continue their own growth through life-long learning.
- ◆ Graduates should be capable of working effectively in an international environment, and be able to succeed in an increasingly interdependent world where borders between cultures and economies are becoming less distinct. They should appreciate the traditions and languages of other cultures, and value diversity in their own society.
- ◆ Graduates should exhibit ethical behavior and integrity. They should also demonstrate perseverance and have pride in accomplishment. They should assume a responsibility to enhance their professions through service and leadership and should be responsible citizens who serve society, particularly through stewardship of the environment.

Student Honor Code

Preamble: The students of Colorado School of Mines (Mines) have adopted the following Student Honor Code (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 Judicial Panel.

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.

History of CSM

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. New methods of exploration, mining and recovery were needed. A number of men with names like Loveland, Berthoud, Arthur Lakes, George West and the Episcopal Bishop Randall proposed a school of mines. In 1874 the Territorial Legislature passed an appropriation of \$5,000 and commissioned W.A.H. 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. With the achievement of statehood in 1876, the Colorado School of Mines was constitutionally established. The first diploma was awarded in 1882.

As CSM grew, its mission expanded. From a rather narrow initial focus on nonfuel minerals, it developed programs as well in petroleum production and refining. More recently it has expanded into the fields of materials science and engineering, energy and environmental engineering, and economics as well as a broader range of engineering and applied science disciplines. CSM 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.

CSM has always had an international reputation in resource fields. Graduates have come from nearly every nation in the world and alumni can be found in nearly every nation.

The student body was predominantly white male for many years, reflecting the demographics of the industries it served. The School gave one of the early engineering degrees for women to Florence Caldwell in 1897 but there were many subsequent years when there were no female students. This has changed and today approximately 23% of the overall student body are women and 14% of the undergraduates are under-represented minorities, thanks to strong recruiting efforts and the opening up of traditionally white male industries.

Unique Programs

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

In addition to these traditional programs which define the institutional focus, the school is pioneering programs in interdisciplinary areas. One of the most successful of these is the Engineering Division program, which currently claims more than one-third of the undergraduate majors. This program combines civil, electrical, environmental and mechanical engineering in a nontraditional curriculum that is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012 – telephone (410) 347-7700. Another, at the graduate level, is the Master of International Political Economy of Resources. Such programs serve as models at CSM.

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

Location

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

Accreditation

Colorado School of Mines is accredited through the doctoral degree by the Higher Learning Commission (HLC) of the North Central Association, 30 North LaSalle Street, Suite 2400, Chicago, Illinois 60602-2504 – telephone (312) 263-0456. The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 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.

Administration

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

Section 2- Student Life

Facilities

Student Center

The Ben H. Parker Student Center has recently undergone a four million dollar renovation and addition. The building contains the offices for the Vice President of Student Life and Dean of Students, the Director of Student Life, Housing, Conferences Reservation Office, Student Activities and Greek Advisor, ASCSM Offices, and Student Groups. The Student Center also contains the student dining hall, the I-Club, a food court, game room, bookstore, and student lounges and TV room. There are also a number of meeting rooms and banquet facilities in the Student Center. Another addition was completed during the summer of 2001 which contains meeting rooms and banquet facilities as well as the Admissions, Financial Aid and Registrar's Offices, Career Services, International Student Services, the Cashier's Office, and Student Development and Academic Support Services.

Services

Academic Advising

Freshmen are advised under the Freshman Mentor Program, designed

- ◆ to ease the transition from high school or work to college,
- ◆ to provide quality academic advising,
- ◆ to provide a resource/contact person for critical periods during the freshman year, and
- ◆ to give students an opportunity to get to know a campus professional.

Each mentor, who is a member of the faculty or professional staff, advises approximately 10 students. Undecided transfer students are advised by the Admissions Office during their first year. Upper class students and transfer students who have declared a major are advised by an advisor in their option department.

Questions concerning work in a particular course should be discussed with the course instructor. General academic program scheduling and planning questions can be answered by the student's advisor or mentor. The advisor's or mentor's signature is required on the early registration form filed by every student. A student meets with the mentor or advisor before registration. An advising hold is placed on the student before registration until the student's advisor clears the advising hold.

Office for Student Development and Academic Services

The Student Development and Academic Services Office (SDAS), located in the Student Center, serves as the personal, academic and career counseling center. Through its various services, the center acts as a comprehensive resource for the personal growth and life skills development of our students. SDAS houses a library of over 300 books and other

materials for checkout, and is home to CSM's Engineers Choosing Health Options (ECHO), promoting wise and healthy decision making regarding students' use of alcohol and other drugs.

Counseling: Experienced, professional counselors offer assistance in a variety of areas. Personal counseling for stress management, relationship issues, wellness education and/or improved self image are a few of the areas often requested. Gender issues, personal security, and compatibility with roommates are also popular interactive presentations. SDAS works closely with other student life departments to address other issues.

Academic Services: The staff often conducts workshops in areas of interest to college students, such as time management, learning skills, test taking, preparing for finals and college adjustment. Advising on individual learning skills is also available.

Tutoring and Academic Excellence Workshops: Free walk-in tutoring is available to all CSM students for most freshmen and sophomore courses. Tutoring in some upper division courses is available. Weekly academic excellence workshops in introductory calculus, chemistry, and physics are provided as well.

International Student Affairs

International student advising and international student services are the responsibility of International Student and Scholar Services, located in the Student Center. The International Student and Scholar Services Office coordinates the Host Family Program. Orientation programs for new international students are held at the beginning of each semester. Visas and work permits are processed through the International Student Advisor at the International Student and Scholar Services Office.

Office of International Programs/Study Abroad

The Office of International Programs (OIP), a program in Academic Affairs located in Stratton Hall, room 109, develops international opportunities for students and faculty at CSM, including study abroad programs. For information about the international activities of OIP, see p. 111.

Identification Cards (BLASTER CARD)

Blaster cards are made in the Student Life Office in the Parker Student Center, and all new students must have a card made as soon as possible after they enroll. Each semester the Student Activities Office issues validation stickers for student ID's, and students can replace lost, stolen, or damaged Blaster Cards for a small fee.

The Blaster Card can be used as a debit card to make purchases from all campus vending machines, at all campus food service facilities, at the campus bookstore, to use any campus laundry facility as well as any campus copying

machine, to check material out of the CSM Library and to make purchases at the campus residence halls and may be required to attend various CSM campus activities.

Please visit the website at <http://www.is.mines.edu/BlasterCard> for more information.

Student Health Center

The Student Health Center, located at 17th and Elm, provides primary health care to CSM students and their spouses. Students pay a \$45 fee each semester which entitles them to unlimited visits with a physician or nurse as well as prescription and over the counter medications. The health center also provides wellness education, immunizations, allergy shots, flu shots, nutrition counseling and information regarding a wide range of health concerns. Staff members are also available to provide health-promotion events for students groups and residence hall program. The Student Health Center is open Monday through Friday 8-12 and 1-4:45 P.M. It is staffed by RN's throughout the day. Physicians coverage is provided by family practice physicians who are on site for two hours daily and on-call at all times.

Dental services are also provided at the Student Health Center. These services are provided by a dentist who has scheduled hours two days per week four hours per day. Basic services such as x-rays, cleanings, fillings and extractions are available.

To be eligible for care, students must be enrolled in four or more hours; have paid the Health Center fee if they are part time and have a completed Health History Form on file at the Health Center. Supervised by Vice President and Dean of Student Life. Phone: (303) 273-3381; FAX: (303) 279-3155.

Motor Vehicles Parking

All students are permitted to bring motor vehicles on campus but they must be registered with CSM Public Safety. Regulations for parking may be obtained from CSM Public Safety. Some parking space is restricted, and this must be observed.

Career Center (Placement and Cooperative Education)

The Career Center assists and advises students in their search for engineering-related employment. Each year industry and government representatives visit the campus to interview students and explain employment opportunities. Fall is the major recruiting season for both summer and full-time positions, but interviews take place in the spring as well. Students must be registered with the Career Center in order to interview, which is accomplished by submitting resumes and signing a card giving the Center permission to disseminate student materials.

A Career Manual is available to students to help in resume writing, interviewing and off-campus job search. Staff members offer individual critiques of resumes and letters, and

personal job search advice. A small library of directories and other job search materials is available for check-out. Many workshops are offered throughout the year on job search topics, and video-taped practice interviewing is available.

The Career Center sponsors a Career Day each fall and spring to allow students to explore career options with exhibiting employers. A Shadowing Program is available for students who wish to visit a local professional in order to clarify career goals. For students undecided about which engineer or science career to pursue, career counseling is provided.

The Cooperative Education Program is available to students who have completed three semesters at CSM (two for transfer students). It is an academic program which offers 3 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. Part-time CO-OP is also possible if a student is working 20 hours per week for several semesters. Students must register for CO-OP while on the job (a no credit, no fee class), and must write learning objectives and sign informal contracts with their company's representative to ensure the educational component of the work experience.

Full-time, part-time, summer and CO-OP jobs are publicized in the Career Center as well as on bulletin boards around the campus. Students are often contacted by the Career Center regarding specific opportunities, and resumes are sent by the Center directly to employers. CSM graduates are eligible for the services of the Career Center for 18 months after graduation. Information on starting salaries, summer salaries, job search success rates, and other topics is collected and available through the Center.

Standards, Codes of Conduct

Every fall, each student is supplied with a Student Handbook that lists all School regulations governing conduct, including discrimination, alcoholic beverages, drugs, academic dishonesty, and distribution of literature, as well as the process for filing a complaint. Anyone having additional questions concerning these regulations should contact the Dean of Students.

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.

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. A Board of Student Publications acts in an advisory capacity to the publications staffs and makes recommendations on matters of policy. The Public Affairs Department staff members serve as daily advisors to the staffs of the Oredigger and Prospector. The Division of Liberal Arts and International Studies provides similar service to the *High Grade*.

Veterans Counseling

The Registrar's Office provides veterans counseling services for students attending the School and using educational benefits from the Veterans Administration.

Tutoring

Individual tutoring in most courses is available through the Office for Student Development and Academic Services. This office also sponsors group tutoring sessions and Academic Excellence Workshops which are open to all interested CSM students. For more information about services and eligibility requirements, contact the Student Development and Academic Services office.

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

The WISEM office in Academic Affairs is located in 300 Guggenheim Hall. 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 for women students and faculty and produces the Chevron Lecture Series. For further information, contact: Debra K. Lasich, Executive Director of Women in Science, Engineering and Mathematics, Colorado School of Mines, 1500 Illinois, Golden, CO 80401-1869, or call (303) 273-3097.

Minority Engineering Program

The Minority Engineering Program is located at 1112 18th Street. The MEP meets the needs of minority students by providing various student services, summer programs, recruitment, academic/retention programs (academic advising, academic excellence workshops, counseling, tutoring and peer study groups), professional/career development (leadership workshops, career development, time management, study skills and national conferences), community outreach and cultural and social activities.

Working through student professional societies—American Indian Science and Engineering Society (AISES), Asian Student Association (ASA), National Society of Black Engineers (NSBE), and Society of Hispanic Professional Engineers (SHPE)—the Office of Minority Engineering Program is a center for minority student activities, and a place for students to become a community of scholars with common goals and objectives in a comfortable learning environment.

The American Indian Science and Engineering Society (AISES) chapter was established at the Colorado School of Mines in 1992. It is a peer support group for Native American students pursuing science and engineering careers. Its main goal is to help the students get through college so they can then use those new skills to create a better life for themselves and other Native Americans.

Asian Students Association (ASA) - This is a branch of the Minority Engineering Program which acknowledges the Asian heritage by involvement in various school activities, social activities, and activities with the other Minority Engineering chapters. ASA allows students with an Asian heritage or students interested in Asian heritage to assemble and voice shared interests and associate in organized group activities which include attending Nuggets games, bowling, ice skating and numerous other activities.

National Society of Black Engineers - NSBE is a non-profit organization managed by students. It was founded to promote the recruitment, retention and successful graduation of Black and other under-represented groups in the field of engineering. NSBE operates through a university-based structure coordinated through regional zones, and administered by the National Executive Board. The local chapters, which are the center of NSBE activity, create and conduct projects in the areas of pre-college student interaction, university academic support mechanisms and career guidance programs. "We instill pride and add value to our members which causes them to want to give back to NSBE in order to produce a continuum of success."

Society of Hispanic Professional Engineers (SHPE) - SHPE is a non-profit organization that exists for the advancement of Hispanic engineering (sciences) students to become professional engineers and scientists, to increase the number of Hispanics entering into the field of engineering, and to develop and implement programs benefiting Hispanics seeking to become engineers and scientists. Anyone interested in joining may do so. SHPE is a national organization with student and professional chapters in nearly 100 cities across the country. The organization is divided into five regions representing 76 student chapters. The SHPE organization is governed by a National Board of Directors which includes representatives from all regions including two student representatives.

Activities

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, responsibility, 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 serves ASCSM as the campus special events board. The majority of all student campus events are planned by the MAC committees. These committees are: **Friday Afternoon Club (FAC)**, which provides comedians and other performing artists to the campus on most Fridays throughout the academic year; **Special Events** which coordinates events such as the annual Back to School Bashes, Discount Sport Nights at Rockies or Avalanche Games, and one time specialty entertainment; 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, oil-field olympics, and softball, just to name a few. Additional events include a huge fireworks display, 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 entire year's activities. 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 slopes.

Living Groups

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.

Social Fraternities, 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. Additionally, the Greek social life provides a complement to the scholastic programs at Mines. 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 recognize different achievements in our students. The Colorado School of Mines honor societies, and their representative areas, are as follows:

Alpha Phi Omega - Service
Alpha Sigma Mu - Metals
Blue Key - Service, Scholarship, Activities
Kappa Mu Epsilon - Mathematics
Order of Omega
Pi Epsilon Tau - Petroleum Engineering
Tau Beta Pi - Engineering

Interest Organizations

Interest organizations meet the special and unique needs of the CSM student body by providing co-curricular activities in specific areas. These organizations are:

Amnesty International
Anime Club
Association of Geoscience Students (AGS)
Ballroom Dance
Band
Bioengineering Club
Campus Crusade for Christ
Capoeira Clubs
Choir

CSM Ambassadors
Earthworks
Fellowship of Christian Athletes
Fellowship of Christian Cowboys
High Grade
Math Club
Mines Little Theatre
Non Traditional Students
Oredigger
Prospector
Students for Creative Anachronism

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. These organizations are:

Chinese Student Association
International Student Organization
Japanese Student Association
Kuwaiti Student Association
Middle Eastern Student Association
Muslim Student Association
Omani Student Association
Taiwanese Student Association

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.

The Colorado School of Mines chapters are as follows:

American Association of Drilling Engineers (AADE)
American Association of Petroleum Geologists (AAPG)
American Institute of Chemical Engineers (AIChE)
American Institute of Mining, Metallurgical & Petroleum Engineers (AIME)
American Institute of Professional Geologists (AIPG)
American Ceramic Society (Am. Cer. Soc.)
American Chemical Society
American Indian Science & Engineering Society (AISES)
American Society of Civil Engineers (ASCE)
American Society of Mechanical Engineers (ASME)
American Society of Metals (ASM International)
American Welding Society
Asian Student Association (ASA)
Association of Engineering Geologists (AEG)
Association of General Contractors (AGC)
Institute of Electrical & Electronic Engineers (IEEE)
National Society of Black Engineers (NSBE)

Society of American Military Engineers (SAME)
Society of Automotive Engineers (SAE)
Society of Economics and Business
Society of Economic Geologists (SEG)
Society of Hispanic Professional Engineers (SHPE)
Society of Mining Engineers (SME)
Society of Petroleum Engineers (SPE)
Society of Physics Students (SPS)
Society of Student Geophysicists (SSG)
Society of Women Engineers (SWE)
The Minerals, Metals & Materials Society of AIME

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. These clubs are:

Bicycle Club
Bridge Club
Caving Club
Cheerleading
Ice Hockey Club
Kayak Club
Kendo Club
Lacrosse Club
Men's Volleyball
Outdoor Club
Racquetball Club
Rugby Club
Shooting Club
Ski Club/Team
Tae Kwon Do Club
Ultimate Frisbee
Water Polo Club
Willie Wonka Boarders
Women's Soccer

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.

Student Honors

Awards are presented each year to members of the graduating class and others in recognition of students who have maintained a superior scholastic record, who have distinguished themselves in school activities, and who have done exceptional work in a particular subject.

Robert F. Aldredge Memorial Award. A cash award, presented in geophysics for the highest scholastic average in geophysics courses.

American Institute of Chemists Award. A one year membership, presented in chemistry and chemical engineering for demonstrated scholastic achievement, leadership, ability, and character.

Robert A. Baxter Award. A cash award, given for meritorious work in chemistry.

Charles N. Bell, 1906, Award. A Brunton transit is awarded for completing the course in mining to the student demonstrating the most progress in school work during each year.

The Brunton Award in Geology. A Brunton transit is awarded in recognition of highest scholastic achievement and interest in and enthusiasm for the science of geology.

Hon. D. W. Brunton Award. A Brunton transit, provided for by Mr. Brunton, is awarded for meritorious work in mining.

The Leo Borasio Memorial Award. A plaque and cash award presented each year to the outstanding junior in the McBride Honors Program. Mr. Borasio was a 1950 graduate of the School of Mines.

Clark B. Carpenter Award. A cash award given to the graduating senior in mining or metallurgy who, in the opinion of the seniors in mining and metallurgy and the professors in charge of the respective departments, is the most deserving of this award.

Clark B. Carpenter Research Award. A cash award presented in honor of Professor Clark B. Carpenter to a student or students, undergraduate or graduate, selected by the Department of Metallurgical Engineering on the basis of scholastic ability and accomplishment. This award derives from an endowment by Leslie E. Wilson, E.M., 1927.

Mary and Charles Cavanaugh Memorial Award. A cash award given in metallurgy based on scholarship, professional activity, and participation in school activities.

Colorado Engineering Council Award. A silver medal presented for excellence in scholarship, high integrity, and general engineering ability.

Distinguished Military Graduate. Designated by the ROTC professor of military science for graduating seniors who possess outstanding qualities of leadership and high moral character, and who have exhibited a definite aptitude for and interest in military service.

Dwight D. "Ike" Eisenhower Award. Provided for by Mr. and Mrs. R. B. Ike Downing, \$150 and a medal with plaque is awarded to the outstanding ROTC cadet commissioned each year, based on demonstrated exemplary leadership within the Corps of Cadets and academic excellence in military science.

Prof. Everett Award. A cash award presented to an outstanding senior in mathematics through the generosity of Frank Ausanka, '42.

Cecil H. Green Award. A gold medal given to the graduating senior in geophysical engineering, who in the opinion of the Department of Geophysics, has the highest attainment in the combination of scholastic achievement, personality, and integrity.

The Neal J. Harr Memorial Outstanding Student Award. Provided by the Rocky Mountain Association of Geologists, the award and rock hammer suitably engraved, presented in geology for scholastic excellence in the study of geology with the aim of encouraging future endeavors in the earth sciences.

Harrison L. Hays, '31, Award. A cash award presented in chemical and petroleum-refining for demonstrating by scholarship, personality, and integrity of character, the general potentialities of a successful industrial career.

John C. Hollister Award. A cash award is presented to the most deserving student in Geophysics and is not based solely on academic performance.

Robert M. Hutchinson Award for Excellence in Geological Mapping. An engraved Brunton Compass given in recognition of this phase of Geological Engineering.

Henry W. Kaanta Award. A cash award and plaque is presented to a graduating senior majoring in extractive metallurgy or mineral processing for the outstanding paper written on a laboratory procedure or experimental process.

Maryanna Bell Kafadar Humanities Award. The award is for the graduating senior who has excelled in the Humanities.

Alan Kissock, 1912, Award. A cash award is presented in metallurgy for best demonstrating the capability for creativity and the ability to express it in writing.

George C. Marshall Award. A certificate, an official biography of General Marshall and an expense paid trip to the National Security Conference sponsored by the Marshall Foundation, is presented to the most outstanding ROTC cadet who demonstrates those leadership and scholastic qualities which epitomized the career of General Marshall.

Metallurgical Engineering Faculty Award. An engraved desk set is presented from time to time by the faculty of the department to a graduating senior who, by participation in and contribution to campus life, and by academic achievement, has demonstrated those characteristics of a well-rounded graduate to which CSM aspires.

Evan Elliot Morse Memorial Award. A cash award is presented annually to a student in physics who, in the opinion of the Physics Department faculty, has shown exceptional competence in a research project.

Old Timers' Club Award. A suitable gift is presented to a graduating senior who, in the opinion of the Department of Mining Engineering, has shown high academic standing in coal mining engineering and potential in the coal industry.

Outstanding Graduating Senior Awards. A suitably engraved plaque is presented by each degree-granting department to its outstanding graduating senior.

H. Fleet Parsons Award. A cash award presented for outstanding service to the School through leadership in student government.

Maxwell C. Pellish, 1924, Academic Achievement Award. A suitably engraved plaque presented to the graduating senior with the highest cumulative grade point average who has had a minimum of 6 semesters at CSM.

The Thomas Philipose Outstanding Senior Award. A plaque and cash award, presented to a senior in the McBride Honors Program in Public Affairs for Engineers whose scholarship, character, and personality best exemplify the ideals of the program as determined by the Committee of tutors.

Physics Faculty Distinguished Graduate Award. Presented from time to time by the faculty of the department to graduating engineering physics seniors with exceptionally high academic achievement in physics.

George R. Pickett Memorial Award. A cash award presented to a graduating senior on the basis of demonstrated interests and accomplishments in the study of borehole geophysics.

President's Senior Scholar Athlete Award. A plaque presented to the graduating senior who has the highest academic average and who lettered in a sport in the senior year.

Ryan Sayers Memorial Award. Presented to a graduating senior in Engineering Physics and/or Mathematical and Computer Sciences in recognition of outstanding academic achievement and performance of significant research as an undergraduate.

William D. Waltman, 1899, Award. Provided for by Mr. Waltman, a cash award and suitably engraved plaque is presented to the graduating senior whose conduct and scholarship have been most nearly perfect and who has most nearly approached the recognized characteristics of an American gentleman or lady during the recipient's entire collegiate career.

H.G. Washburn Award. A copy of *De Re Metallica* by Agricola is awarded in mining engineering for good scholastic record and active participation in athletics.

Charles Parker Wedgeforth Memorial Award. Presented to the most deserving and popular graduating senior.

Section 3 - Tuition, Fees, Financial Assistance, Housing

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.

Undergraduate Tuition

The official tuition and approved charges for the 2006-2007 academic year will be available prior to the start of the 2006-2007 academic year located at

http://www.is.mines.edu/budget/budget_current/tuition_rates.pdf

Fees

Regular Semester (Fall/Spring)

During a regular semester, students taking less than 4 credit hours are not required to pay student fees, except for the Technology Fee. Any such student wishing to take part in student activities and receive student privileges may do so by paying full semester fees. All students carrying 4 or more credit hours must pay full student fees as follows:

Health Center*	\$45.00
Associated Students	75.70
Athletics	49.00
Student Services	192.00
Student Assistance	15.00
Technology Fee	60.00
Recreation Center**	55.00
Total	\$491.70

*A health insurance program is also available. Health insurance is a mandatory fee unless the student can prove coverage through another plan.

**Fee will increase to \$85.00 for the spring semester.

Summer Session

Academic Courses

Health Center	\$22.50
Athletics	24.50
Student Services	96.00
Technology Fee	30.00
Student Assistance	7.50
Recreation Center (summer 2007)	42.50
Total	\$223.00

Field Term Courses

On-campus:

Health Center	\$17.00
Student Services	72.00
Technology Fee	30.00
Rec. Center	32.00
Total	\$151.00

Off-campus: Arrangements and payment for transportation, food, lodging, and other expenses must be made with the department concerned. (Geology Department camping fee is \$350.)

Miscellaneous

New Student Orientation	\$40.00
(exempt from refund policy)	
New International Stu. Orient	\$75.00
(exempt from refund policy)	
Chem Lab Fee	\$30.00
Graduation (Bachelors)	\$100.00
Student Health Insurance	\$660.00

Military Science

Lab Fee	\$175.00
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Descriptions of Fees and Other Charges

The following mandatory, non-waivable fees are charged by the Colorado School of Mines to all students enrolled for 4.0 semester hours or more:

Health Center Fee - Revenues support physician/medical services to students \$45.00/term

Associated Students Fee - Revenues support student organizations/ events/activities; e.g., newspaper, homecoming, E-days Expenditures must be approved by ASCSM \$75.70/term

Athletics Fee - Revenues support intercollegiate athletics and entitle student entrance to all CSM scheduled events and use of the facilities \$49.00/term

Student Assistance Fee - Funds safety awareness programs, training seminars for abuse issues, campus lighting, and parking facility maintenance \$15.00/term

Student Services Fee - Revenues support bond indebtedness and other student services; e.g., Career Center, Student Development Center, Student Activities, Student Life, and services provided in Student Life \$192.00/term

Technology Fee - Funds technology infrastructure and equipment for maximum student use. The School matches the student fee revenues dollar for dollar \$60.00/term

Recreation Center Fee - Revenues help pay for new recreation center. Fee passed in student election in March 2002. \$55.00/term
Beginning Spring 2007. \$85.00/term

The following mandatory, waivable fee is charged by the Colorado School of Mines to all degree seeking students, regardless of full-time or part-time student status:

Student Health Insurance - Revenues contribute to a self-insurance fund. \$660.00

The following are established fees that are case dependent.

Late Insurance Waiver Fee - Revenues provide funds for the administration of the health insurance program \$60.00

Chemistry Lab Fee - Revenues provide a contingency against breakage of laboratory equipment; e.g., test tubes, beakers, etc \$30.00/course

Field Camp Fee - Revenues support the instructional activities/ services provided during Field session \$100.00 - \$800.00 depending on Dept

Military Science Lab Fee - Revenues support the instructional activities of the Military Science Department. . . . \$175.00 ROTC

New Student Orientation Fee - Revenues support the new student orientation program provided to freshmen and transfer students at the start of the Fall and Spring semesters. This fee is exempt from refund policy \$40.00

New International Students \$75.00

On-line Course Fee \$40.00/credit hour

Summer Orientation Fee - Revenues support the Explore CSM programs provided to freshmen students and their parents during the summer \$55.00

Transcript Fee - Revenues support the cost of providing transcripts. \$2.00/copy

Add/Drop Charge - Revenues offset the cost of processing Add/Drop registration. \$4.00 each

Late Payment Penalty - Revenues offset billing costs for late payments 1.5% per month of outstanding balance

Credit Card Fee 2.0% of charge

Housing Application Fee \$50.00

Damage Deposit, (Housing) (Freshmen housing exempt) - Revenues are used to repair or replace damaged items/rooms in CSM housing units. Mines Pk \$400.00

Bike Locker Rental - Revenues go to provide and maintain locker facilities for residence hall student bicycles \$50.00/sem

Residence Hall Room Charge - Revenues support maintenance, improvements and residence hall administration See Housing Rates in next section

Meal Plan Charges - Revenues provide meals and maintain cafeteria equipment for the students on meal plans See Meal Plans in next section

Residence Hall Association Fee - Revenues support social activities for the residence hall students. \$50.00/year

Housing and Rental Fees - Rental fees for housing rentals go to maintain the rental properties, pay utility charges, and maintain and improve properties See Housing Rates in next section

Tuition Paid-Out - CSM has advanced tuition to another school. Charges are reimbursement request for those advances. Only for sponsored students Paid by sponsor

Books/Supplies Fee - Advances made to or on behalf of the student. Charges are reimbursement only. Only for sponsored students Paid by sponsor

Computer Usage Fees - Revenues assist in providing research computing services. \$500.00/term Paid by sponsor

Refunds or Advances - These charges are reimbursement requests for funds advanced to or on behalf of the student. Funds received replace those advances N/A

Payments - CSM must repay to the bank any student funds for which a student becomes ineligible. Funds collected from the student replace those payments. N/A

Grants and Scholarships (Recalled) When students become ineligible for grant, loan or scholarship money which they have received, the recall of those funds are reflected. N/A

Return Check - The amount of a student's check which has been returned for insufficient funds. N/A

Returned Check Charge - Revenues offset bank fees for returned checks \$32.00

In all instances, the costs to collect these fees are not reimbursed to the Student Receivables Office. The Colorado School of Mines does not automatically assess any optional fees or charges.

Housing

NOTE: Room and board charges are established by the Board of Trustees (BOT) and are subject to change. Payment of room and board charges fall under the same guidelines as payment of tuition and fees. Rates below are in effect for the 2006-2007 Academic year. Included is a "flexible" meal plan which guarantees students a designated number of meals per week and gives them between \$50.00 - \$175.00 to spend as they wish on additional meals or any of the other food service establishments. For more information, please contact the Student Life Office at (303) 273-3350.

Rates for 2006-2007 (per year)

Residence Halls (Students must choose a meal plan)

Morgan/Thomas/Bradford/Randall Halls

Double Room	\$3,695
Single Room	\$4,375
Double Room as Single.	\$4,700

Weaver Towers

Double Room	\$3,935
Single Room	\$4,580
Double Room as Single.	\$4,945
"E" Room, Single	\$4,930

Residence Hall Association Fee . . . \$50 included above

Residence Halls at Mines Park (freshmen only)

Double occupancy room	\$3,900
Single occupancy room	\$4,585

Sigma Nu House \$3,800

FIJI \$4,160

Alpha Phi Sorority \$3,930

Pi Phi Sorority \$3,930

Sigma Kappa Sorority \$3,930

All CSM owned Fraternity and Sorority

Houses—Summer \$50/week

Resident Meal Plans

Marble.	\$3,290 (per year)
19 meals/week + \$50 Munch Money/semester	
Quartz	\$3,290 (per year)
15 meals/week + \$100 Munch Money/semester	
Granite	\$3,290 (per year)
150 meals/semester + \$175 Munch Money/semester	
Topaz (Mines Park Resident Only)	
.	\$3,290 (per year)
125 meals/semester + \$250 Munch Money/semester	

Field Session (Six weeks)

Double Room	\$350
Single Room.	\$610

Summer Session (Eight weeks)

Double Room	\$455
Single Room.	\$725

Field Sessions and Summer Session Meal Plans

Gold Card (declining balance). . Any Amount

*Mines Park**

Family Housing

- 1 Bedroom. \$650/month
- 2 Bedroom. \$750/month

Apartment Housing

- 1 Bedroom \$650
- 2 Bedroom \$878
- 3 Bedroom. \$1,170

*Tenant pays gas and electricity only

CSM pays water/sewer/public electric. Tenant pays \$18.50/month per phone line (optional).

Residence Hall Application

Information and application for residence hall space is included in the packet offering admission to the student. Students desiring accommodations are requested to forward their inquiries at the earliest possible date.

The submission of a room application does not in itself constitute a residence hall reservation. A residence hall contract will be mailed to the student to be signed by the student and his or her parents and returned to the Residence Life Office. Only upon receipt and written acknowledgement of the residence hall contract by the Residence Life Office will the student be assured of a room reservation.

Rooms and roommates are assigned in accordance with student preference insofar as possible, with earlier applications receiving priority.

Advance Deposits

An advance deposit of \$50 made payable to Colorado School of Mines must accompany each application received. This deposit will be refunded in full (or in part if there are charges against the room) when the student leaves the residence hall.

If a student wishes to cancel a residence hall reservation, \$25 of the deposit will be refunded if notice of the cancellation is received in writing by the Residence Life Office on or before May 1 of the current year.

Contracts are issued for the full academic year and no cancellation will be accepted after May 1, except for those who decide not to attend CSM. Those contracts separately issued only for entering students second semester may be cancelled no later than December 15. After that date no cancellation will be accepted except for those who decide not to attend CSM.

Payments and Refunds

Payment Information

A student is expected to complete the registration process, including the payment of tuition and fees, room and board, before attending class. Students can mail their payment to:

Cashier
1600 Maple Street
Colorado School of Mines
Golden, CO 80401-1887

Financial Responsibility

It is important for students to recognize their financial responsibilities when registering for classes at the school. If students do not fulfill their financial obligations by published deadlines:

- ✓ Late payment penalties will accrue on any outstanding balance.
- ✓ Transcripts will not be issued.
- ✓ Past due accounts will be turned over to Colorado Central Collection Services in accordance with Colorado law.
- ✓ Collection costs will be added to a student's account.
- ✓ The student's delinquency may be reported to national credit bureaus.

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. Students will be responsible for all collection costs.

Encumbrances

A student will not be permitted to register for future classes, graduate, or secure an official transcript of his/her academic record while indebted in any way to CSM. Students will be responsible for payment of all reasonable costs of collection.

Refunds

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

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

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

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 pro-rated to the date of checkout from the Residence Hall. Arrangements must be made with the Housing Office. Student health insurance charges are not refundable. The insurance remains in effect for the entire semester.

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.

State of Colorado Residency Qualifications

A student is classified as a resident or nonresident for tuition purposes at the time admission is granted. The classification is based upon information furnished by the student. The student who, due to subsequent events, becomes eligible for resident tuition must make formal application to the Registrar for a change of status.

A student who willfully gives wrong information to evade payment of nonresident tuition shall be subject to serious disciplinary action. The final decision regarding tuition status rests with the Tuition Appeals Committee of Colorado School of Mines.

Resident Students

A person whose legal residence is permanently established in Colorado may continue to be classified as a resident student so long as such residence is maintained even though circumstances may require extended absences from the state.

Qualification for resident tuition requires both (1) proof of adoption of the state as a fixed and permanent home, demonstrating physical presence within the state at the time of such adoption, together with the intention of making Colorado the true home; and (2) living within the state for 12 consecutive months immediately prior to the first day of classes for any given term.

These requirements must be met by one of the following: (a) the father, mother, or guardian of the student if an unemancipated minor, or (b) the student if married or over 22, or (c) the emancipated minor.

The home of the unemancipated minor is assumed to be that of the parents, or if there is a legal guardian of the student, that of such guardian. If the parents are separated or divorced and either separated or divorced parent meet the Colorado residency requirements, the minor also will be considered a resident. Statutes provide for continued resident status, in certain cases, following parents' moving

from Colorado. Please check Colorado Revised Statutes 1973, 23-7-103(2)(m)(II) for exact provisions. In a case where a court has appointed a guardian or granted custody, it shall be required that the court certify that the primary purpose of such appointment was not to qualify the minor for resident tuition status.

Nonresident Students

To become a resident of Colorado for tuition classification under state statutes, a student must be domiciled in Colorado for one year or more immediately preceding the first day of class for the semester for which such classification is sought. A person must be emancipated before domicile can be established separate from the domicile of the parents. Emancipation for tuition purposes takes place automatically when a person turns 22 years of age or marries.

The establishment of domicile for tuition purposes has two inseparable elements: (1) a permanent place of habitation in Colorado and (2) intent to remain in Colorado with no intent to be domiciled elsewhere. The twelve-month waiting period does not begin until both elements exist. Documentation of the following is part of the petitioning process to document physical presence: copies of rental arrangements, rent receipts, copy of warranty deed if petitioner owns the personal residence property and verification of dates of employment. Documentation of the following is part of the petitioning process to document intent: Colorado drivers license, motor vehicle registration (as governed by Colorado Statute), voter registration, payment of Colorado state income taxes, ownership of residential real estate property in the state (particularly if the petitioner resides in the home), any other factor peculiar to the individual which tends to establish the necessary intent to make Colorado one's permanent place of habitation.

Nonresident students wishing to obtain further information on the establishment of residency or to apply for resident status should contact the Registrar's Office. The "Petition for In-State Tuition Classification" is due in the Registrar's Office by the first day of classes of the term the student is requesting resident status.

College Opportunity Fund

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

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

Who is eligible? Undergraduate students who are eligible for in-state tuition, and who apply for COF, are admitted to and enrolled in an eligible institution of higher education, and who authorize the institution to collect the funds on their behalf. Once enrolled at the Colorado School of Mines, the

student must authorize the School to collect these funds from the state on the student's behalf. Once authorized, the School will continue to collect these funds on the student's behalf unless and until the student chooses to revoke the authorization.

How much is the stipend? It will vary. The amount will be determined each year by the Colorado Legislature. Currently, it is estimated to be approximately \$86 per credit hour for the academic year 2006-2007.

For additional information please refer to:

Colorado School of Mines website:
<http://www.mines.edu/admin/cof/>

Colorado Commission on Higher Education's website:
<http://www.state.co.us/cche/>

The College Opportunity Fund website:
<https://cof.college-access.net/cofapp/>

Financial Aid and Scholarships

Undergraduate Student Financial Assistance

The role of the CSM Financial Assistance Program is to enable students to enroll and complete their educations, regardless of their financial circumstances. In fulfilling this role, the Office of Financial Aid administered over \$28 million in total assistance in 2005-2006, including over \$10.2 million in grants and scholarships. Additional information may be found at the CSM financial aid web site, www.finaid.mines.edu.

Applying for Assistance

The CSM Application for Admission serves as the application for CSM merit-based scholarships for new students (the Athletic and Military Science Departments have their own application procedures for their scholarships). Continuing students may be recommended by their major department for scholarships designated for students from that department. To apply for need-based CSM, federal and Colorado assistance, students should complete the Free Application for Federal Student Aid.

After the student's and family's financial circumstances are reviewed, a financial aid award is sent to the student. New students are sent an award letter beginning in late March, and continuing students are notified in mid May.

Types of Financial Assistance

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

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

Student Loans may be offered from two federal programs:

the Perkins Student Loan, or the Stafford Student Loan.

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

The Alumni Association of CSM administers a loan program designed to assist juniors and seniors who have exhausted their other sources of funds. These are short term loans which require repayment within three years after graduation, and have been made available through the contributions of CSM alumni.

Merit-based assistance is offered to recognize students who have special talents or achievements. Academic awards to new students are made on the basis of their high school records, SAT or ACT test scores, academic interests, and extracurricular activities. Continuing students receive scholarships based on their academic performance at CSM, particularly in their major field of study, and on financial need.

Alumni Association Grants are awarded to students who are children of alumni who have been active in the CSM Alumni Association for the two years prior to the student's enrollment. The one-year grants carry a value of \$1,000. The students may also receive a senior award, based on their academic scholarship, and the availability of funds.

Engineers' Day Scholarships are available to Colorado residents. Based on high school records, an essay, and other information, a CSM Student Government committee selects students for these four-year awards.

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

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

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

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

In addition to scholarships through CSM, many students receive scholarships from their hometown civic, religious or other organizations. All students are urged to contact organi-

zations with which they or their parents are affiliated to investigate such scholarships. The Financial Aid Office reserves the right, unless otherwise instructed by the student, to release the student's information to scholarship providers for the purpose of assisting students in obtaining scholarships.

Financial Aid Policies

General

CSM students requesting or receiving financial assistance sponsored by the U.S. Government, the State of Colorado, or the Colorado School of Mines are required to report to the CSM Financial Aid Office all financial assistance offered or received from all sources including CSM immediately upon receipt or notification of such assistance. For the purpose of this paragraph, "financial assistance" shall include, but not be limited to, grants, scholarships, fellowships, or loans funded by public or private sources, as well as all income not considered taxable income by the Internal Revenue Service. Upon receipt of this information, CSM shall evaluate, and may adjust any financial assistance provided to the student from CSM, Colorado, or federal funds. No student shall receive financial assistance from CSM if such student's total assistance from all sources exceeds the total cost of the student's education at CSM. For the purpose of this paragraph, the "total cost of education" shall be defined to include the cost of tuition, fees, books, room and board, necessary travel, and reasonable personal expenses.

Funds for the Federal Pell Grant, Federal Supplemental Educational Opportunity Grant, Federal College Work-Study Program, Federal Perkins Loan, Federal Stafford Loan, and Federal Parent Loan for Undergraduate Students are provided in whole or part by appropriations of the United States Congress. The Colorado General Assembly provides funds for the Colorado Grant, Colorado Leveraging Educational Assistance Program, Colorado Merit Scholarship, Colorado Athletic Scholarship, and Colorado Work-Study programs. These programs are all subject to renewed funding each year.

Satisfactory Academic Progress

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

Students receiving assistance from federal, Colorado or need-based CSM funds must make satisfactory academic progress toward their degree. Satisfactory progress is defined as successfully completing a minimum of 12 credits each semester with a minimum 2.000 grade average. Students who register part-time must successfully complete all of the credits for which they register with a minimum 2.000 grade average. If students are deficient in either the credit hour or grade average measure, they will receive a one semester probationary period during which they must return to satisfactory standing by completing at

least 12 credits with a minimum 2.000 grade average. If this is not done, their eligibility will be terminated until such time as they return to satisfactory standing. In addition, if students totally withdraw from CSM, or receive grades of F in all of their courses, their future financial aid eligibility will be terminated. Students receiving all F's for a semester will have their financial assistance retroactively terminated unless they can prove class attendance. Financial aid eligibility termination may be appealed to the Director of Financial Aid on the basis of extenuating or special circumstances having negatively affected the student's academic performance.

Study Abroad

Students who will be studying abroad through a program sponsored by CSM may apply for all forms of financial assistance as if they were registered for and attending classes at CSM. Financial assistance will be based on the student's actual expenses for the program of study abroad.

For additional information about Study Abroad opportunities, contact the Office of International Programs, Stratton 109; (303) 384-2121.

Refunds

If students completely withdraw from all of their classes during a semester, they may be eligible for a refund (a reduction in tuition and fees, and room or board if they live on campus, and a return of funds to the financial aid programs from which the student is receiving assistance). If a student is receiving federal or Colorado assistance, there will be no refund given after the date on which students have completed at least 60% of the semester. The refund will be calculated as required by Federal law or regulation, or by the method described in the section on "Payments and Refunds," using the method that will provide the largest reduction in charges for the student. For the purposes of this policy, the official withdrawal date is the date as specified on the withdrawal form by the student. If the student withdraws unofficially by leaving campus without completing the check-out procedure, the official withdrawal date will be the last date on which the student's class attendance can be verified.

Section 4 - Living Facilities

Residence Halls

Colorado School of Mines has five residence halls for men and women. The traditional style includes Bradford, Randall, Morgan, and Thomas Halls with primarily double bedrooms and a bathroom on each floor. There are a limited number of single rooms available. Weaver Towers features seven or eight person suites with each suite containing both single and double bedrooms, a living/study room and two bathrooms. Each Residence Hall complex houses mailboxes, lounge areas, TV room, and coin operated washers and dryers. Each occupant has a wardrobe or closet, storage drawers, mirror, a study desk and chair, and a wall bookshelf. All rooms are equipped with data connections, cable TV (basic) service, a phone (campus, with optional voice mail), and upgraded electrical systems. The student is responsible for damage to the room or furnishings. Colorado School of Mines assumes no responsibility for loss or theft of personal belongings. Living in the CSM Residence Halls is convenient, comfortable, and provides the best opportunity for students to take advantage of the student activities offered on campus.

Dining Facilities

Colorado School of Mines operates a dining hall in the Ben H. Parker Student Center. Under the provisions for the operation of the residence halls, students who live in the residence halls are required to board in the School dining hall. Breakfast, lunch and dinner are served Monday through Friday, lunch and dinner on Saturday and brunch and dinner on Sunday. Students not living in a residence hall may purchase any one of several meal plans which best meets their individual needs. No meals are served during breaks (Thanksgiving, Christmas and Spring Break).

Mines Park

The Mines Park apartment complex is located west of the 6th Avenue and 19th Street intersection on 55 acres owned by CSM. The complex houses some freshmen, upper class and graduate students, and families. Residents must be full-time students.

Units are complete with refrigerators, stoves, dishwashers, cable television and campus phone lines and T-1 connections to the campus network system. There are two community centers which contain laundry facilities, recreational/study space, and a convenience store.

Rates are as follows:

Mines Park Family Housing

1 bedroom	\$650/mo
2 bedroom	\$750/mo

Mines Park Apartment Housing

1 bedroom	\$650/mo
2 bedroom	\$878/mo
3 bedroom	\$1,170/mo

For an application to any of the campus housing options, please contact the Housing Office at (303) 273-3350 or visit the Student Life office in the Ben Parker Student Center, Room 218.

Fraternities, Sororities

A student who is a member of one of the national Greek organizations on campus is eligible to live in Fraternity or Sorority housing. Most of the organizations have their own houses, and provide room and board to members living in the house. All full time, undergraduate students are eligible to join these organizations. For information, contact the Student Activities office or the individual organization.

Private Rooms, Apartments

Many single students live in private homes in Golden. Colorado School of Mines participates in no contractual obligations between students and Golden citizens who rent rooms to them. Rents in rooming houses generally range from \$400 to \$450 a month. Housing is also available in the community of Golden, where apartment rental ranges from \$575 to \$1,050 a month.

Section 5 - Undergraduate Information

Undergraduate Bulletin

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

Admission Requirements

Colorado School of Mines admits students who have demonstrated the ability to do classroom and laboratory work and profit from our programs. The decision to admit a student is based on his or her ability to earn a degree at CSM. Criteria considered in evaluating students include (1) pattern of course work in high school or college, (2) grades earned in those courses, (3) rank in class, (4) ACT or SAT test scores, and (5) other available test scores. No single criterion for admission is used; however, the most important factor is the academic record in high school or college.

The admission requirements below are minimum requirements which may change after a catalog has been printed. The Board of Trustees, CSM's governing board, reserves the right to deviate from published admission requirements. In such cases, changes in admission policy would be widely publicized.

Freshmen

The minimum admission requirements for all high school graduates who have not attended a college or university are as follows:

1. An applicant must be a graduate of an accredited high school.

2. An applicant should rank in the upper one-third of their graduating class. Consideration will be given to applicants below this level on evidence of strong motivation, superior test scores, and recommendation from principal or counselor.

3. The following 16 units of secondary school work must be completed upon graduation from high school:

Algebra	2
Geometry	1
Advanced Mathematics (including Trigonometry)	1
English	4
History or Social Studies	2
Academic Elective	3
Laboratory Science	3

One unit of laboratory science must be either chemistry or physics. The second and third units may be chemistry, physics, zoology, botany, geology, etc. with laboratory. Both physics and chemistry are recommended for two of the three required units. General Science is not acceptable as a science unit, however it is acceptable as an academic elective unit.

4. The 3 units of academic electives (social studies, mathematics, English, science, or foreign language) must be acceptable to the applicant's high school to meet graduation requirements. For applicants submitting GED Equivalency Diplomas, these units may be completed by the GED test.

5. Applicants from the United States and Canada are required to submit the scores of either the Scholastic Aptitude Test (SAT) of the College Entrance Examination Board or the American College Test (ACT) battery. Applications for either the SAT or ACT may be obtained from the high school counselors, or by writing to Educational Testing Service, P.O. Box 592, Princeton, NJ 08541 for the SAT; or to the American College Testing Program, P.O. Box 168, Iowa City, IA 52243 for the ACT. You may also register online at www.collegeboard.com (SAT) and www.act.org (ACT).

Transfer Students

An applicant to CSM is considered to be a transfer student if he or she has enrolled in coursework at another college after graduating from high school. The minimum admissions requirements for all transfer students are as follows:

1. Students transferring from another college or university must have completed the same high school course requirements as entering freshmen. A transcript of the applicant's

high school record is required. ACT or SAT test scores are not required if the student has completed a minimum of 30 credit hours of college credit.

2. Applicants must present official college transcripts from all colleges attended. Applicants should have an overall 2.75 (C+) grade point average or better. Students presenting a lower GPA will be given careful consideration and acted on individually.
3. An applicant who cannot re-enroll at the institution from which he or she wishes to transfer because of scholastic record or other reason will be evaluated on a case-by-case basis.
4. Completed or “in progress” college courses - which meet CSM graduation requirements - are eligible for transfer credit if the grade earned is a “C” or better.

Former Students

The minimum admission requirements for those students who have previously attended CSM are as follows:

1. Any student who has attended another college or university since last enrolling at CSM must apply for admission as a transfer student.
2. Any student who did not complete the semester immediately preceding the beginning of the period for which he or she wishes to enroll must be re-admitted to CSM by the Admissions Office.
3. A former student, returning after a period of suspension, must apply for admission to the Admissions Office and must furnish an approval for such re-enrollment from the Readmissions Committee of Colorado School of Mines. Appropriate forms to apply for admission may be obtained from the Admissions Office.

International Students

The minimum admission requirements for those students who are not citizens of the United States or Canada are as follows:

1. Students from outside the United States and Canada must meet the specified unit requirements in secondary education for entering freshmen, or for students entering after having completed some college education. Students from countries using the English system of examinations must have earned First Class or First Division rank on their most recent examination to be eligible for admission.
2. The Test of English as a Foreign Language (TOEFL) is required of all international students whose native language is not English. Information and application forms for this test, which is given four times each year all over the world, may be obtained from the College Entrance Examination Board, P.O. Box 592, Princeton, NJ 08541, U.S.A. Or online at www.toefl.org.

3. If a TOEFL exam score indicates that the applicant will be handicapped academically, as a condition for admission the applicant may be required to enroll in the INTERLINK Language program until the required proficiency is achieved. The INTERLINK Language program at Colorado School of Mines offers intensive English language instruction and skills development for academic success. See the detailed description of INTERLINK in Section 8 of this *Bulletin*.

Nondegree Students

A nondegree student is one who has not applied to pursue a degree program at CSM but wishes to take courses regularly offered on campus. Such students may take any course for which they have the prerequisites as listed in the CSM Bulletin or have the permission of the instructor. Transcripts or evidence of the prerequisites are required. An applicant for admission to the undergraduate school who does not meet admission requirements may not fulfill deficiencies through this means. Exception to this rule can be made only by the Director of Enrollment Management. A maximum of 12 hours of nondegree credit from Colorado School of Mines may be transferred to an undergraduate degree program.

Admission Procedures

All Applicants

Documents received by CSM in connection with applications for admission or transfer of credit will not be duplicated, returned to the applicant, or forwarded to any agency or any other institution.

A \$45.00 non-refundable application fee is required from all applicants.

Applications for undergraduate study cannot be accepted later than 21 days prior to the date of registration confirmation for any academic semester or summer session. Admission for any semester or term may close whenever CSM's budgeted number of students has been met.

High School Graduates

Colorado high school applicants should obtain applications from their high school counselor or principal or write the Admissions Office. Out-of-state applicants should write the Admissions Office, Colorado School of Mines, 1600 Maple Street, Golden, CO 80401, for application forms. Applicants can apply online at www.mines.edu.

A student may apply for admission any time after completing the 11th grade. The application will be evaluated upon receipt of the completed application form, a high school transcript showing courses completed, courses remaining to be completed, ranking in class, other pertinent data, and SAT or ACT test scores. In some cases, the grades or marks received in courses taken during the first half of the senior year may be required. Applicants who meet freshman admission requirements are admitted subject to completion of all entrance requirements and high school graduation.

Transfer Students **Guaranteed Transfer**

Colorado School of Mines is a signatory to the Colorado Statewide Engineering Articulation Agreement, which can be viewed at www.state.co.us/cche. Beginning with admissions in 2003–2004, this agreement determines transferability of coursework for engineering students in the State of Colorado. All students transferring into CSM under the terms of the statewide agreement are strongly encouraged to be advised by the CSM Admissions Office on their planned course of study. Credits earned more than 10 years previously will not transfer.

Additionally, Colorado School of Mines has formal transfer agreements with Red Rocks Community College (RRCC), www.rrcc.ccooes.edu/transfer/csm.htm, and Front Range Community College (FRCC), www.FrontRange.edu. Students are encouraged to contact the Admissions Office at either institution for additional information.

Transfer by Review

Undergraduate students at another college or university who wish to transfer to CSM should request an application for admission from the Admissions Office or apply online at www.mines.edu.

A transfer student should apply for admission at the beginning of the final quarter or semester of attendance at his or her present college. The application will be evaluated upon receipt of the completed application form, high school transcript, transcripts from each university or college attended, and a list of courses in progress. The Admissions Office will then notify the student of his or her admission status. Admission is subject to satisfactory completion of current courses in progress and submission of a final transcript.

Advanced Placement and International Baccalaureate

Course work completed for select subjects under the Advanced Placement Program in a high school may be accepted for college credit provided that the Advanced Placement Program Test grade is either 5 (highest honors) or 4 (honors). For a score of three (credit) on the test, credit may or may not be given subject to a study of the A.P. test and related materials, placement test data, high school record, and other test scores available. No credit will be given if the test grade is 2 (pass) or 1 (fail).

In special cases, advanced placement may be granted for course work not completed under the College Entrance Examination Board Program. Students wishing such credit may demonstrate competence by writing the Advanced Placement Examination on the subject. Information can be secured from the College Entrance Examination Board, P.O. Box 592, Princeton, NJ 08541. More information on which subjects are accepted can be found on the web at www.mines.edu

Course work completed for select subjects under the International Baccalaureate Program in high school may be accepted for college credit provided that the International Baccalaureate Program Exam grade is a 5, 6, or 7 on selected standard and higher level exams. In some cases, departmental approval is required before credit is granted. More information on which subjects are accepted can be found on the web at www.mines.edu

Declaration of Option (Major)

The curriculum during the first two semesters at CSM is the same for everyone; therefore, students are not required to choose a major before the end of the freshman year. All students must have declared a major by the beginning of the junior year.

Medical Record

A health history prepared by the student, a medical examination performed by the student's physician and an updated immunization record completed by the student and the physician, nurse or health authority comprise the medical record. A medical record is required for full time students entering CSM for the first time, or following an absence of more than 12 calendar months.

The medical record will be sent to the student after acceptance for admission. The medical record must be updated and completed and then returned to the Student Health Center before permission to enroll is granted. Proof of immunity consists of an official Certificate of Immunization signed by a physician, nurse, or public health official which documents measles, mumps and rubella immunity. The Certificate must specify the type of vaccine and the dates (month, day, year) of administration or written evidence of laboratory tests showing immunity to measles, mumps and rubella.

The completed medical record is confidential and will be kept in the Student Health Center. The record will not be released unless the student signs a written release.

Veterans

Colorado School of Mines is approved by the Colorado State Approving Agency for Veteran Benefits under chapters 30, 31, 32, 35, and 1606. Undergraduates must register for and maintain 12 credit hours, and graduate students must register for and maintain 10 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, addresses, marital status, or dependents are to be reported to the Veterans Certifying Officer as soon as possible so that overpayment or under payment 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.

Academic Regulations

Deficiencies

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

Prerequisites

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

Remediation

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

Transfer Credit

New Transfer Students

Upon matriculation, a transfer student will receive the prescribed academic credit for courses taken at another institution if these courses are listed in a current articulation agreement and transfer guide between CSM and that institution. Credits earned more than 10 years in advance of admission will not transfer. When an articulation agreement does not exist with another institution, the transfer student may receive credit for a course taken at another institution, subject to review by the appropriate CSM department head or designate to ensure course equivalency.

Continuing Students

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

Returning Students

Students who have matriculated at CSM, withdrawn, applied for readmission and wish to transfer in credit taken at an institution while they were absent from CSM, must obtain

approval, upon return, of the department head of the appropriate course, the department head of the student's option, and the Registrar.

In all cases, requests for transfer credit are processed by the Registrar. Credits must be submitted on an official transcript from an accredited institution. Only courses with grades of "C" or better will be accepted.

Course Withdrawals, Additions and Drops

Courses may be added or dropped without fee or penalty during the first 11 school days of a regular academic term (first 4 school days of a 6-week field course or the first 6 school days of the 8-week summer term).

Continuing students may withdraw from any course after the eleventh day of classes through the tenth week for any reason with a grade of W. After the tenth week, no withdrawals are permitted except in cases of withdrawal from school or for extenuating circumstances under the auspices of the Office of Academic Affairs and the Office of the Registrar. A grade of F will be given in courses which are withdrawn from after the deadline without approval.

Freshmen in their first and second semesters and transfer students in their first semester are permitted to withdraw from courses with no grade penalty through the Friday prior to the last week of classes.

All adds/drops are initiated in the Registrar's Office. To withdraw from a course (with a "W") a student must obtain the appropriate form from the Registrar's office, have it initialed by the instructor and signed by the student's advisor/mentor to indicate acknowledgment of the student's action, and return it to the Registrar's Office by close of business on the last day that a withdrawal is authorized. Acknowledgment (by initials) by the division/department is required in only 2 cases: 1. when a course is added after the 11th day of the semester and 2. when the Registrar has approved, for extenuating circumstances, a withdrawal after the last date specified (a "late withdrawal"). Approval of a late withdrawal can be given by the Registrar acting on behalf of the Office of Academic Affairs in accordance with CSM's refund policy, and in compliance with federal regulations.

A \$4.00 fee will be charged for any change in class schedule after the first 11 days of class, except in cases beyond the student's control or withdrawal from school. All adds/drops are initiated in the Registrar's Office.

Independent Study

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

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.

Absenteeism

Class attendance is required of all undergraduates unless the student is representing the School in an authorized activity, in which case the student will be allowed to make up any work missed. Students who miss academic work (including but not limited to exams, homework, labs) while participating in school sponsored activities must either be given the opportunity to make up this work in a reasonable period of time or be excused from such work. It is the responsibility of the student to initiate arrangements for such work. Proof of illness may be required before makeup of missed work is permitted. Excessive absence may result in a failing grade in the course. Determination of excessive absence is a departmental prerogative.

The Office of the Dean of Students, if properly informed, will send a notice of excused absence of *three days or more* to faculty members for (1) an absence because of illness or injury for which documentation will be required; (2) an absence because of a death in the immediate family, i.e., a spouse, child, parent, grandparent, or sibling. For excused absences students must be provided the opportunity to make up all missed work.

Withdrawal from School

A student may officially withdraw from CSM by processing a *Withdrawal from School* form available in the Student Development Office. Completion of the form through the Student Development Office prior to the last day of scheduled classes for that term will result in W's being assigned to courses in progress. Failure to officially withdraw will result in the grades of courses in progress being recorded as F's. Leaving school without having paid tuition and fees will result in a hold being placed against the transcript. Either of these actions would make future enrollment at CSM or another college more difficult.

Undergraduate Grading System

Grades

When a student registers in an undergraduate course (400-level and lower), one of the following grades will appear on

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

A	Excellent
B	Good
C	Satisfactory
D	Poor (lowest passing)
F	Failed
S	Satisfactory, C or better, used at mid-term
U	Unsatisfactory, below C, used at mid-term
WI	Involuntarily Withdrawn
W	Withdrew, No Penalty
T	Transfer Credit
PRG	In Progress
PRU	In Progress Unsatisfactory
INC	Incomplete
NC	Not for Credit
Z	Grade not yet submitted
M	Thesis Completed

Undergraduate students enrolled in graduate-level courses (500-level) are graded using the graduate grading system. See the CSM Graduate Bulletin for a description of the grading system used in graduate-level courses.

Incomplete Grade

If a student, because of illness or other reasonable excuse, fails to complete a course, a grade of INC (Incomplete) is given. The grade INC indicates deficiency in quantity of work and is temporary.

A GRADE OF INC MUST BE REMOVED NOT LATER THAN THE FIRST FOUR WEEKS OF THE FIRST SEMESTER OF ATTENDANCE FOLLOWING THAT IN WHICH IT WAS RECEIVED. Upon failure to remove an INC within the time specified, it shall be changed to an F (failed) by the Registrar.

Progress Grade

The progress grade (PRG) is used primarily for multi-semester courses, such as thesis or certain special project courses which are spread over two terms. The progress grade will be awarded in MACS111, MACS112, and PHGN100 to students completing the course for the FIRST time who would otherwise have received a grade of "D" (an enrollment with a grade of "W" is not considered a completion). Subsequent to receiving a grade of "PRG," a student must receive a grade of "D" or higher to move on to the next course in a sequence. The progress grade carries earned hours. However, it does not affect quality points or quality hours (gpa), nor is it sufficient to meet degree requirements.

Forgiveness of “F” Grade

When a student completing MACS111 or MACS112 or PHGN100 for the FIRST time receives an “F” in the course but subsequently receives a grade of “D” or higher in that course, the “F” received for the first completion will be changed to a “W”. If the student receives a “PRG” grade (see above), an “F” in any subsequent semester will not be forgiven.

The table below outlines different scenarios associated with this policy. A “W” is not considered a completion and will not affect the actions below, regardless of when a “W” is received.

1st Completion	2nd Completion	3rd Completion	Action Taken
PRG	D or better	—	No grades are changed; student can move on
PRG	F	D or better	No grades are changed; student can move on
F	D or better	—	F is changed to a W; student can move on
F	F	D or better	First F is changed to a W; student can move on

NC Grade

A student may for special reasons, with the instructor’s permission, register in a course on the basis of NC (Not for Credit). To have the grade NC appear on his/her transcript, the student must enroll at registration time as a NC student in the course and comply with all conditions stipulated by the course instructor, except that if a student registered as NC fails to satisfy all conditions, no record of this registration in the course will be made.

Grade Appeal Process

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

If a student believes he or she has been unfairly graded, the student may appeal this decision first to the instructor of the course, and if the appeal is denied, to the 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.
2. The grading decision was based on standards that were unreasonably different from those applied to other students in the same section of that course.
3. The grading decision was based on standards that differed substantially and unreasonably from those previously articulated by the instructor.

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

1. The student should prepare 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 should deliver this appeal to the course instructor and attempt to resolve the issue directly with the instructor. Written grade appeals must be delivered to the instructor no later than 10 business days after the start of the regular (fall or spring) semester immediately following the semester in which the contested grade was received. In the event that the course instructor is unavailable because of leave, illness, sabbatical, retirement, or resignation from the university, the course coordinator (first) or the Department Head/Division Director (second) shall represent the instructor.
3. If after discussion with the instructor, the student is still dissatisfied, he or she can proceed with the appeal by 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 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, and the course instructor’s Department Head/Division Director.
4. The Faculty Affairs Committee will request a response to the appeal from the instructor. On the basis of its review of the student’s appeal, the instructor’s response, and any other information deemed pertinent to the grade appeal, the Faculty Affairs Committee will determine whether the grade should be revised. The decision rendered will be either: 1) the original grading decision is upheld, or 2) sufficient evidence exists to indicate a grade has been assigned un-

fairly. In this latter case, the Faculty Affairs Committee will assign the student a new grade for the course. The Committee's decision is final. 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 15 business days following the Senate's receipt of the grade appeal.

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

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. The system for expressing the quality of a student's work is based on quality points and quality hours. The grade A represents four quality points, B three, C two, D one, F none. 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 of A, B, C, D, or F 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.

Transfer Credit

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

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. No full-time undergraduate student may enroll for more than 19 credit hours in one semester. Physical education, advanced ROTC and Honors Program in Public Affairs courses are excepted. However, upon written recommendation of the faculty advisor, the better students may be given permission by the Associate Vice President of Academic Affairs and the Registrar to take additional hours.

Grade-Point Averages

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

Overall Grade-Point Average

The overall grade-point average includes all attempts of courses taken at Colorado School of Mines. The minimum overall grade-point average required to earn a Mines undergraduate degree is a 2.000.

Option (Major) Grade-Point Average

The grade-point average calculated for the option (major) includes all attempts at courses completed in the major department at Colorado School of Mines. In some cases, additional courses outside of the major department are also included in the major gpa calculation. The minimum major grade-point average required to earn a Mines undergraduate degree is a 2.000. For specifics concerning your major gpa, reference your online degree audit or contact your major department.

Honor Roll and Dean's List

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

Graduation Awards

Graduation awards are determined by the student's cumulative academic record at the end of the preceding semester. For example, the overall gpa earned at the end of the fall term determines the awarding of high honors for the purposes of May commencement. Students achieving a cumulative grade-point average of 3.5 or above at the end of the preceding term will have "High Honors" inscribed on the metal diploma as well as the official transcript.

Metal diplomas for undergraduates are ordered well before the commencement ceremony and cannot include grade calculations for the term of completion (spring term in the above example). Students achieving a cumulative grade-point average of 3.5 or above only at the end of their undergraduate career will have "High Honors" listed on the official transcript. The student may choose to order an additional metal diploma at the student's own expense from the Registrar's Office.

Good Standing

A student is in good standing at CSM when he or she is enrolled in class(es) and is not on either academic or disciplinary probation. Provisional probation does not affect a student's being in good standing.

Academic Probation and Suspension Probation

A student whose cumulative grade-point average falls below the minimum requirements specified (see table below) will be placed on probation for the following semester. A student on probation is subject to the following restrictions:

1. may not register for more than 15 credit hours

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

When a part-time degree undergraduate has attempted a total of 12 quality hours of credit with a cumulative grade point average of less than 2.0, the student will be placed on academic probation by the Dean of Students. Should students not earn a 2.0 grade-point average for the next semester of attendance, they will be subject to suspension.

Suspension

A student on probation who fails to meet both the last semester grade period requirements and the cumulative grade-point average given in the table below will be placed on suspension. A student who meets the last semester grade period requirement but fails to achieve the required cumulative grade-point average will remain on probation.

Total Quality Hours	Required Cumulative G.P. Average	Last Semester G.P. Average
0-18.5	1.7	—
19-36.5	1.8	2.0
37-54.5	1.8	2.0
55-72.5	1.9	2.1
73-90.5	1.9	2.1
91-110.5	2.0	2.2
111-130.5	2.0	2.2
131-150.5	2.0	2.3

A freshman or transfer student who fails to make a grade-point average of 1.5 during the first grade period will be placed on suspension.

Suspension becomes effective immediately when it is imposed. Readmission after suspension requires written approval from the Readmissions Committee. While a one semester suspension period is normally the case, exceptions may be granted, particularly in the case of first-semester freshmen and new transfer students.

No student who is on suspension may enroll in any regular academic semester without the written approval of the Readmissions Committee. However, a student on suspension may enroll in a summer session (field camp, academic session, or both) with the permission of the Dean of Students. Students on suspension who have been given permission to enroll in a summer session by the Dean may not enroll in any subsequent term at CSM without the written permission of the Readmissions Committee. Readmissions Committee meetings are held prior to the beginning of each regular semester and at the end of the spring term.

A student who intends to appear in person before the Readmissions Committee must register in the Dean of Students Office in person or by letter. Between regular meetings of the Committee, in cases where extensive travel would be required to appear in person, a student may petition in writing to the Committee, through the Dean of Students.

Appearing before the Readmissions Committee by letter rather than in person will be permitted only in cases of extreme hardship. Such cases will include travel from a great distance, e.g. overseas, or travel from a distance which requires leaving a permanent job. Appearing by letter will not be permitted for continuing students in January.

The Readmissions Committee meets immediately before classes start and the first day of classes. Students applying for readmission must appear at those times except under conditions beyond the control of the student. Such conditions include a committee appointment load extending beyond the first day of classes, delay in producing notice of suspension or weather conditions closing highways and airports.

All applications for readmission after a minimum period away from school, and all appeals of suspension or dismissal, must include a written statement of the case to be made for readmission.

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

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

Notification

Notice of probation, suspension, or dismissal will be mailed to each student who fails to meet catalog requirements.

Repeated Failure

A student who twice fails a required course at Colorado School of Mines and is not subject to academic suspension will automatically be placed on “Special Hold” status with the Registrar, regardless of the student’s cumulative or semester GPA. The student must meet with the Readmissions Committee and receive written permission before being allowed to register. Transfer credit from another school will not be accepted for a twice-failed course.

Access to Student Records

Students at the Colorado School of Mines are protected by the Family Educational Rights and Privacy Act of 1974

(FERPA), 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 FERPA office 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: Undergraduate-Registrar; Graduate-Graduate Dean
2. Transcript of Grades: Registrar
3. Computer Grade Lists: Registrar
4. Encumbrance List: Controller and Registrar
5. Academic Probation/Suspension List: Undergraduate-Dean of Students; Graduate-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: Undergraduate-Registrar; Graduate-Graduate Dean
9. Financial Aid File: Financial Aid (closed records)
10. Medical History File: School Physician (closed records)

Student Access to Records. The undergraduate student wishing access to a record will make written request to the Dean of Students. The graduate student will make a similar request to the Dean of the Graduate School. 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 student's

dean to arrange a mutually satisfactory time for review. This time will be as soon as practical but is not to be later than 45 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 appropriate 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 statute 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.

General Information

Academic Calendar

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

Classification of Students

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

Freshmen	0 to 29.9 semester credit hours
Sophomore	30 to 59.9 semester credit hours
Junior	60 to 89.9 semester credit hours
Senior	90 or more semester credit hours

Part-Time Degree Students

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

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

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

Seniors in Graduate Courses

With the consent of the student's department/division and the Dean of Graduate Studies, a qualified senior may enroll in 500-level courses without being a registered graduate student. At least a 2.5 GPA is required. The necessary forms for attending these courses are available in the Registrar's Office. Seniors may not enroll in 600-level courses. Credits in 500-level courses earned by seniors may be applied toward an advanced degree at CSM only if:

1. The student gains admission to the Graduate School.
2. The student's graduate committee agrees that these credits are a reasonable part of his graduate program.
3. The student provides proof that the courses in question were not counted toward those required for the Bachelor's Degree.
4. Graduate courses applied to a graduate degree may not count toward eligibility for undergraduate financial aid. This may only be done if a student has been admitted to a Combined BS/MS degree program and has received the appropriate prior approvals.

Undergraduate students enrolled in graduate-level courses (500-level) are graded using the graduate grading system. See the CSM Graduate Bulletin for a description of the grading system used in graduate-level courses.

Course Substitution

To substitute credit for one course in place of another course required as part of the approved curricula in the catalog, a

student must receive the approval of the Registrar, the heads of departments of the two courses, the head of the student's option department. There will be a periodic review by the Office of the Executive Vice President for Academic Affairs. Forms for this purpose are available in the Registrar's Office.

Change of Bulletin

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

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

Students' Use of English

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

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

The LAIS Writing Center is available to assist students with their writing. For additional information, contact the LAIS Division, Stratton 301; 303-273-3750.

Summer Session

The summer session is divided into two independent units: a period not to exceed 6 weeks for required field and laboratory courses and an 8-week on-campus summer school during which some regular school year courses are offered.

Dead Week

All final examinations will take place during the examinations week specified in the Academic Calendar. With the possible exception of laboratory examinations, no other examinations will be given during the week preceding examinations week (Dead Week).

Dead Day

No academic meetings, examinations or activities may take place on the Friday immediately preceding final exams for the fall and spring terms.

Final Examination Policy

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

In general, all final examinations will be given only during the stated final examination period and are to appear on the Registrar's schedule. Faculty policy adopted in January 1976

provides that no exams may be given during the week preceding examinations week (dead week), with the possible exception of laboratory exams. The scheduling by an individual faculty member of a final exam during dead week is to be avoided because it tends to hinder the students' timely completion of other course work and interfere with the schedules of other instructors. Faculty members should not override this policy, even if the students in the class vote to do so.

Full-time Enrollment

Full-time enrollment for certification for Veterans Benefits, athletics, loans, most financial aid, etc. is 12 credit hours per semester for the fall and spring semesters. Full-time enrollment for field session is 6 credit hours, and full-time enrollment for summer session is 6 credit hours.

Curriculum Changes

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

Undergraduate Degree Requirements

Bachelor of Science Degree

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

Bachelor of Science (Chemical Engineering)
Bachelor of Science (Chemistry)
Bachelor of Science (Economics)
Bachelor of Science (Engineering)
Bachelor of Science (Engineering Physics)
Bachelor of Science (Geological Engineering)
Bachelor of Science (Geophysical Engineering)
Bachelor of Science (Mathematical and Computer Sciences)
Bachelor of Science (Metallurgical & Materials Engineering)
Bachelor of Science (Mining Engineering)
Bachelor of Science (Petroleum Engineering)

Graduation Requirements

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

1. A minimum cumulative grade-point average of 2.000 for all academic work completed in residence.
2. A minimum cumulative grade-point average of 2.000 for courses in the candidate's major.
3. A minimum of 30 hours credit in 300 and 400 series technical courses in residence, at least 15 of which are to be taken in the senior year.

4. A minimum of 19 hours in humanities and social sciences courses.
5. The recommendation of their degree-granting department/division to the faculty.
6. The certification by the Registrar that all required academic work is satisfactorily completed.
7. The recommendation of the faculty and approval of the Board of Trustees.

Seniors must submit an Application to Graduate two semesters prior to the anticipated date of graduation. Applications are available in the Registrar's Office.

The Registrar's Office provides the service of doing preliminary degree audits. Ultimately, however, it is the responsibility of students to monitor the progress of their degrees. It is also the student's responsibility to contact the Registrar's Office when there appears to be a discrepancy between the degree audit and the student's records.

All graduating students must officially check out of School. Checkout cards, available in the Dean's Office, must be completed and returned one week prior to the expected date of completion of degree requirements.

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

Multiple Degrees. A student wishing to complete Bachelor of Science degrees in more than one degree program must receive permission from the heads of the appropriate departments to become a multiple degree candidate. The following requirements must be met by the candidate in order to obtain multiple degrees:

1. All requirements of each degree program must be met.
2. Any course which is required in more than one degree need be taken only once.
3. A course required in one degree program may be used as a technical elective in another, if it satisfies the restrictions of the elective.
4. Different catalogs may be used, one for each degree program.
5. No course substitutions are permitted in order to circumvent courses required in one of the degree programs, or reduce the number of courses taken. However, in the case of overlap of course content between required courses in the degree programs, a more advanced course may be substituted for one of the required courses upon approval of the head of each department concerned, and the Registrar on behalf of the office of Academic Affairs. The course substitution form can be obtained in the Registrar's Office.

Undergraduate Programs

All programs are designed to fulfill the expectations of the *Profile of the Colorado School of Mines Graduate* in accordance with the mission and goals of the School, as introduced on page 5. To enable this, the curriculum is made up of a common core, eleven undergraduate degree granting programs, and a variety of support and special programs. Each degree granting program has an additional set of goals which focus on the technical and professional expectations of that program. The common core and the degree granting programs are coupled through course sequences in mathematics and the basic sciences, in specialty topics in science and/or engineering, in humanities and the social sciences, and in design. Further linkage is achieved through a core course sequence which addresses system interactions among phenomena in the natural world, the engineered world, and the human world.

Through the alignment of the curriculum to these institutional goals and to the additional degree-granting program goals, all engineering programs are positioned for accreditation by the Accreditation Board for Engineering and Technology, and science programs are positioned for approval by their relevant societies, in particular the American Chemical Society for the Chemistry program.

Course Numbering

Numbering of Courses:

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

Course Numbering:

100–199	Freshman level	Lower division
200–299	Sophomore level	Lower division
300–399	Junior level	Upper division
400–499	Senior level	Upper division
500–699	Graduate level	
Over 700	Graduate Research or Thesis level	

Student Life

CSM101. FRESHMAN SUCCESS SEMINAR is a “college adjustment” course, taught in small groups, designed to assist students with the transition from high school to CSM.

Emphasis is placed on appreciation of the value of a Mines education, and the techniques and University resources that will allow freshmen to develop to their fullest potential at CSM. 8 meetings during semester; 0.5 semester hours.

The Core Curriculum

Core requirements for graduation include the following:

In Mathematics and the Basic Sciences, 12 semester hours in Calculus for Scientists and Engineers and 3 semester hours in Differential Equations (2 semester hours in Differential Equations for Geological Engineering majors); 8 semester hours in the Principles of Chemistry; and 9 semester hours in Physics.

In Design, 6 semester hours in Design Engineering Practices Introductory Course Sequence.

In Systems, 7 semester hours in Earth and Environmental Systems (4), and Human Systems (3).

In Humanities and the Social Sciences, 10 semester hours: Nature and Human Values (4), Principles of Economics (3), Human Systems (3) (also partially meets Systems requirement), and a restricted cluster of 9 semester hours in H&SS electives. Note that the Human Systems course is inclusive in both the Humanities and Social Sciences and the Systems core segments. Note that the economics requirement can be satisfied by taking the Microeconomics/Macroeconomics sequence (EBGN311 & EBGN312) instead of taking Principles of Economics. This option is recommended for students considering a major or minor in economics.

In Physical Education, Four separate semesters including PAGN101 and PAGN102 totaling a minimum of 2 credit hours.

In Freshman Orientation and Success, 0.5 semester hours.

Free electives, minimum 9 hours, are included within each degree granting program. With the exception of the restrictions mentioned below, the choice of free elective courses to satisfy degree requirements is unlimited. The restrictions are:

1. The choice must not be in conflict with any *Graduation Requirements* (p. 33).
2. Free electives to satisfy degree requirements may not exceed three semester hours in concert band, chorus, studio art, and physical education and athletics.

The Freshman Year

Freshmen in all programs normally take the same subjects, as listed below:

Fall Semester

<i>subject code** and course number</i>	lec.	lab.	sem.hrs.
CHGN121 Principles of Chemistry I	3	3	4
MACS111 Calculus for Scientists & Engr's I	4		4
SYGN101* Earth and Environmental Systems	3	3	4
LAIS100* Nature and Human Values	4		4
CSM101 Freshman Success Seminar	0.5		0.5
PAGN101 Physical Education I		0.5	0.5
Total			17

Spring Semester

	lec.	lab.	sem.hrs.
CHGN124 Principles of Chemistry I	3		3
CHGN126 Quantitative Chem. Measurements		3	1
MACS112 Calculus for Scientists & Engr's II	4		4
EPIC151* Design I	2	3	3
PHGN100 Physics I	3.5	3	4.5
PAGN102 Physical Education II		2	0.5
Total			16

* For scheduling purposes, registration in combinations of SYGN101, LAIS100 and EPIC151 will vary between the fall and spring semesters. In some cases the combinations may include taking EBGN201 in the freshman instead of the soph-

omore year, whereupon one of the * courses is shifted to the sophomore year. Students admitted with acceptable advanced placement credits will be registered in accordance with their advanced placement status.

**** Key to Subject Codes**

ChEN	Chemical Engineering
CHGC	Geochemistry
CHGN	Chemistry
DCGN	Core Science and Engineering Fundamentals
EBGN	Economics and Business
EGES	Engineering Systems (Engineering)
EGGN	Engineering
EPIC	EPICS
ESGN	Environmental Science and Engineering
GENG	Geological Engineering
GEGX	Geochemical Exploration (Geology)
GEOC	Oceanography (Geology)
GEOG	Geology
GOGN	Geo-Engineering (Mining)
GPGN	Geophysical Engineering
HNRS	Honors Program
LAIS	Liberal Arts & International Studies
LICM	Communication
LIFL	Foreign Languages
LIMU	Band; Choir
MACS	Mathematical & Computer Sciences
MNGN	Mining Engineering
MSGN	Military Science
MTGN	Metallurgical & Materials Engr'ng
PAGN	Physical Education and Athletics
PEGN	Petroleum Engineering
PHGN	Physics
SYGN	Core sequence in Systems

The Sophomore Year

Requirements for the sophomore year are listed within each degree granting program. Continuing requirements for satisfying the core are met in the sophomore, junior and senior years. It is advantageous, but not essential, that students select one of the eleven undergraduate degree programs early in the sophomore year.

Curriculum Changes

In accordance with the statement on Curriculum Changes on page 33, the Colorado School of Mines makes improvements in its curriculum from time to time. To confirm that they are progressing according to the requirements of the curriculum, students should consult their academic advisors on a regular basis and should carefully consult any Bulletin Addenda that may be published.

Special Programs

EPICS (Engineering Practices Introductory Course Sequence)

EPICS is a two-semester sequence of courses for freshman and sophomores, designed to prepare students for their

upper-division courses and to develop some of the key skills of the professional engineer: the ability to solve complex, open-ended problems; the ability to self-educate; and the ability to communicate effectively.

An award-winning program, EPICS replaces the traditional core courses in introductory computing skills, graphics, and technical communication. Whenever possible, instruction in these subjects is “hands-on” and experiential, with the instructor serving primarily as mentor rather than lecturer.

Problem-solving skills are developed through “projects,” open-ended problems, which the students solve in teams. Starting with simple case studies, the projects grow in length and complexity to a final, full-semester project submitted by an external client. The projects require extensive library research and self-education in appropriate technical areas; they also require students to consider non-technical constraints (economic, ethical, political, societal) in arriving at their solutions.

Written and oral communications are studied and practiced as an integral part of the project work. Graphics and computing skills are integrated with projects wherever possible.

Among the topics studied by students in EPICS are: use of the computer as a problem-solving tool, and the use of word-processing, graphics, spreadsheet and CAD packages; 3-D visualization; audience analysis and the preparation of a variety of technical documents; oral communication in the staff format; interpersonal skills in group work; project management.

The EPICS program is required of all undergraduates.

Division of Liberal Arts and International Studies (LAIS) Writing Center

Located in room 311 Stratton Hall (phone: 303-273-3085), the LAIS Writing Center is a teaching facility providing all CSM students with an opportunity to enhance their writing proficiency. The LAIS Writing Center faculty are experienced technical and professional writing instructors. The Center assists writers with all their writing needs, from course assignments to scholarship applications, proposals, letters and resumes. This service is free to CSM students and includes one-to-one tutoring and online resources (at <http://www.mines.edu/Academic/lais/wc/writingcenter.html>).

Writing Across the Curriculum (WAC)

To support the institutional goal of developing professional communication skills, required writing and communication-intensive courses are designated in both the core and in the degree-granting programs. The Campus Writing Program, housed in LAIS, supports the WAC program.

In addition to disciplinary writing experience, students also obtain writing experience outside their disciplines as courses in the Division of Liberal Arts and International Studies are virtually all writing intensive. Writing-intensive courses within the various degree-granting programs are

designated with (WI) in Section 6 of this *Bulletin*, *Description of Courses*.

The Guy T. McBride, Jr. Honors Program in Public Affairs for Engineers

The McBride Honors Program offers a 24-semester-hour program of seminars and off-campus activities that has the primary goal of providing a select number of students the opportunity to cross the boundaries of their technical expertise and to gain the sensitivity to prove, project, and test the moral and social implications of their future professional judgments and activities, not only for the particular organizations with which they will be involved, but also for the nation and the world. To achieve this goal, the Program seeks to bring themes from the humanities and the social sciences into the engineering curriculum to develop in students habits of thought necessary for effective management, social responsibility, and enlightened leadership.

This program leads to a certificate and a Minor in the McBride Honors Program in Public Affairs for Engineers.

Bioengineering and Life Sciences (BELS)

Nine CSM departments and divisions have combined resources to offer a Minor Program and an Area of Special Interest (ASI) in Bioengineering and Life Sciences (BELS). The BELS minor and the ASI are flexible, requiring only one common core course (BELS/ESGN301, General Biology I). The rest of the courses can be chosen, in consultation with a BELS program advisor, from a broad list of electives, allowing students to concentrate their learning in areas such as Biomedical Engineering, Biomaterials, Environmental Biotechnology, Biophysics or Pre-Medical studies. Interested students should consult with the office of Dr. Joel Bach, Brown Building 314A, 303-384-2161, jmbach@mines.edu.

Minor Program/Area of Special Interest

Established Minor Programs/Areas of Special Interest (ASI) are offered by all of the undergraduate degree-granting departments as well as the Division of Environmental Science and Engineering, the Division of Liberal Arts and International Studies, and the Military Science Department.

A MINOR PROGRAM of study consists of a minimum of 18 credit hours of a logical sequence of courses. With the exception of the McBride Honors minor, only three of these hours may be taken in the student's degree-granting department and no more than three of these hours may be at the 100- or 200-level.

An AREA OF SPECIAL INTEREST consists of a minimum of 12 credit hours of a logical sequence of courses. Only three of these hours may be at the 100- or 200-level and no more than three of these hours may be specifically required for the degree program in which the student is graduating.

As a minimum, CSM requires that any course used to fulfill a minor/ASI requirement be completed with a passing grade. Some programs offering minors/ASIs may, however,

impose higher minimum grades for inclusion of the course in the minor/ASI. In these cases, the program specified minimum course grades take precedence. For additional information on program-specific minimum course grade requirements, refer to the appropriate program section of this Bulletin.

As a minimum, to be awarded a minor/ASI, CSM requires students obtain a cumulative GPA of 2.0 or higher in all minor/ASI courses. All attempts at required minor/ASI courses are used in computing this minor/ASI GPA. Some programs offering minors/ASIs may, however, require a higher minimum cumulative GPA. In these cases, the program specified GPA takes precedence. For additional information on program specific GPA requirements, refer to the appropriate section of this Bulletin.

Students may not request more than half of the required courses for the minor or ASI be completed through transfer credit, including AP, IB and CLEP. Some minor/ASI programs, however, have been established in collaboration with other institutions through formal articulation agreements and these may allow transfer credit exceeding this limit. For additional information on program specific transfer credit limits, refer to the appropriate section of this Bulletin.

A Minor Program/Area of Special Interest declaration (which can be found in the Registrar's Office) should be submitted for approval prior to the student's completion of half of the hours proposed to constitute the program, or at the time of application for graduation - whichever comes first. Once the declaration form is submitted to the Registrar's Office, the student deciding not to complete the minor must officially drop the minor by notifying the Registrar's Office in writing. Should minor requirements not be complete at the time of graduation, the minor program will not be awarded. Minors are not added after the BS degree is posted. Completion of the minor will be recorded on the student's official transcript.

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

Study Abroad

Students wishing to pursue study abroad opportunities should contact the Office of International Programs (OIP), listed under the Services section of this Bulletin, p.156. Colorado School of Mines encourages students to include an international study/work experience in their undergraduate education. CSM maintains student exchange programs with engineering universities in South America, Europe, Australia, Africa, and Asia. Courses successfully passed abroad can be substituted for their equivalent course at CSM. Overall GPA is not affected by courses taken abroad. In addition, study abroad can be arranged on an individual basis at universities throughout the world.

Financial aid and selected scholarships and grants can be used to finance approved study abroad programs. The OIP has developed a resource center for study abroad information in its office, 109 Stratton Hall, phone 303-384-2121. Students are invited to use the resource materials and meet with staff to discuss overseas study opportunities.

Core Areas

Design

Engineering Practices Introductory Course Sequence (EPICS)

ROBERT D. KNECHT, Design (EPICS) Program Director and CEPR Research Professor

Freshman Year

EPIC151. Design (EPICS) I introduces a design process that includes open-ended problem solving and teamwork integrated with the use of computer software as tools to solve engineering problems. Computer applications emphasize graphical visualization and production of clear and coherent graphical images, charts, and drawings. Teams assess engineering ethics, group dynamics and time management with respect to decision-making. The course emphasizes written technical communications and introduces oral presentations. 3 semester hours.

Sophomore Year

EPIC251. Design (EPICS) II builds on the design process introduced in Design (EPICS) I, which focuses on open-ended problem solving in which students integrate teamwork and communications with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. Teams analyze team dynamics through weekly team meetings and progress reports. The course emphasizes oral presentations and builds on written communications techniques introduced in Design (EPICS) I. Design (EPICS) II is also offered during the first summer field session in a three-week format. Prerequisite: EPIC151. 3 semester hours.

EPIC252. Leadership Design (EPICS) can be taken in lieu of EPIC251. Leadership Design (EPICS) II builds on the design process introduced in Design (EPICS) I, which focuses on open-ended problem solving in which students integrate skills in teamwork, communications, and computer software to solve engineering problems. This section, however, presents projects, which require strategic planning and community interaction to expose design students to the challenges and responsibilities of leadership. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. Students analyze team dynamics through weekly meetings and

progress reports. The course emphasizes oral presentations and builds on written communications techniques introduced in Design (EPICS) I. In addition, these sections provide instruction and practice in team interactions (learning styles, conflict resolution), project management (case studies, seminars), and policy (multiple clients, product outcome, and impact). Prerequisite: EPIC151. 4 semester hours.

Systems

SYGN101. EARTH AND ENVIRONMENTAL SYSTEMS (I, II, S) Fundamental concepts concerning the nature, composition and evolution of the lithosphere, hydrosphere, atmosphere and biosphere of the earth integrating the basic sciences of chemistry, physics, biology and mathematics. Understanding of anthropological interactions with the natural systems, and related discussions on cycling of energy and mass, global warming, natural hazards, land use, mitigation of environmental problems such as toxic waste disposal, exploitation and conservation of energy, mineral and agricultural resources, proper use of water resources, biodiversity and reconstruction. 3 hours lecture, 3 hours lab; 4 semester hours.

SYGN200. HUMAN SYSTEMS (I, II) This is a pilot course in the CSM core curriculum that articulates with LAIS100: Nature and Human Values and with the other systems courses. Human Systems is an interdisciplinary historical examination of key systems created by humans - namely, political, economic, social, and cultural institutions - as they have evolved worldwide from the inception of the modern era (ca. 1500) to the present. This course embodies an elaboration of these human systems as introduced in their environmental context in Nature and Human Values and will reference themes and issues explored therein. It also demonstrates the cross-disciplinary applicability of the "systems" concept. Assignments will give students continued practice in writing. Prerequisite: LAIS100. 3 semester hours.

SYGN201. ENGINEERED EARTH SYSTEMS (I) An introduction to Engineered Earth Systems. Aspects of appropriate earth systems and engineering practices in geological, geophysical, mining and petroleum engineering. Emphasis on complex interactions and feedback loops within and among natural and engineered systems. A case histories format provides an introduction to earth engineering fields. 2 hours lecture/seminar, 3 hours lab; 3 semester hours.

SYGN202. ENGINEERED MATERIALS SYSTEMS (I, II) Introduction to the structure, properties, and processing of materials. The historical role that engineered and natural materials have made on the advance of civilization. Engineered materials and their life cycles through processing, use, disposal and recycle. The impact that engineered materials have on selected systems to show the breadth of properties that are important and how they can be controlled by proper material processing. Recent trends in materials development mimicking natural materials in the context of the

structure and functionality of materials in living systems. Prerequisites or concurrent: CHGN124, MACS112, PHGN100. 3 hours lecture; 3 semester hours.

SYGN203. NATURAL AND ENGINEERED ENVIRONMENTAL SYSTEMS Introduction to natural and engineered environmental systems analysis. environmental decision making, sustainable development, industrial ecology, pollution prevention, and environmental life cycle assessment. The basic concepts of material balances, energy balances, chemical equilibrium and kinetics and structure and function of biological systems will be used to analyze environmental systems. Case studies in sustainable development, industrial ecology, pollution prevention and life cycle assessment will be covered. The goal of this course is to develop problem-solving skills associated with the analysis of environmental systems. Prerequisites: CHGN124 or concurrent; MACS112 or concurrent; PHGN100; SYGN101. 3 hours lecture; 3 semester hours.

Distributed Core

DCGN209. INTRODUCTION TO CHEMICAL THERMODYNAMICS (I, II, S) Introduction to the fundamental principles of classical thermodynamics, with particular emphasis on chemical and phase equilibria. Volume-temperature-pressure relationships for solids, liquids, and gases; ideal and non-ideal gases. Introduction to kinetic-molecular theory of ideal gases and the Maxwell-Boltzmann distributions. Work, heat, and application of the First Law to closed systems, including chemical reactions. Entropy and the Second and Third Laws; Gibbs Free Energy. Chemical equilibrium and the equilibrium constant; introduction to activities & fugacities. One- and two-component phase diagrams; Gibbs Phase Rule. Prerequisites: CHGN121, CHGN124, MACS111, MACS112, PHGN100. 3 hours lecture; 3 semester hours. Students with credit in DCGN210 may not also receive credit in DCGN209.

DCGN210. INTRODUCTION TO ENGINEERING THERMODYNAMICS (I, II) Introduction to the fundamental principles of classical engineering thermodynamics. Application of mass and energy balances to closed and open systems including systems undergoing transient processes. Entropy generation and the second law of thermodynamics for closed and open systems. Introduction to phase equilibrium and chemical reaction equilibria. Ideal solution behavior. Prerequisites: CHGN121, CHGN124, MACS111, MACS112, PHGN100. 3 hours lecture; 3 semester hours. Students with credit in DCGN209 may not also receive credit in DCGN210.

DCGN241. STATICS (I, II, S) Forces, moments, couples, equilibrium, centroids and second moments of areas, volumes and masses, hydrostatics, friction, virtual work. Applications of vector algebra to structures. Prerequisite: Credit or concurrent enrollment in PHGN100, MACS112, EPIC151 3 hours lecture; 3 semester hours.

DCGN381. INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER (I, II, S) This course provides an engineering science analysis of electrical circuits. The following topics are included: DC and single- and three-phase AC circuit analysis, current and charge relationships. Ohm's Law, resistors, inductors, capacitors, equivalent resistance and impedance, Kirchoff's Laws, Thevenin and Norton equivalent circuits, superposition and source transformation, power and energy, maximum power transfer, first order transient response, algebra of complex numbers, phasor representation, time domain and frequency domain concepts, effective and rms values, complex power, apparent power, power factor, balanced delta and wye line and phase currents, filters, resonance, diodes, EM work, moving charge in an electric field, relationship between EM voltage and work, Faraday's and Ampere's Laws, magnetic reluctance and ideal transformers. Prerequisite: PHGN200. 3 hours lecture; 3 semester hours.

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, or Master's Degree while completing the requirements for their Bachelor's Degree. These combined Bachelor's-Master's programs have been created by CSM faculty in those situations where they have deemed it academically advantageous to treat BS and MS degree programs as a continuous and integrated process. These accelerated programs 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 CSM 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 CSM 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.

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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 Certificate, Professional Master's Degree, or Non-Thesis Master's 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 Bachelor's and Master's Degrees in five years of total enrollment at CSM.

Certain graduate programs may allow Combined 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. Those courses must meet all requirements for graduate credit, and their grades are 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 pro-

grams. 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 fully admitted into a graduate program, undergraduate Combined Degree Program students must maintain good standing in the Combined Degree 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 the Graduate 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 MS degree programs may, with graduate advisor approval, register for 700-level research credits appropriate to Master's-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 this 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 to his/her graduate degree, he/she must notify the Registrar of the intent to do so prior to enrolling in the course. The Registrar will forward this information to the Office of Financial Aid for appropriate action. If prior consent is not received, all 500-level graduate courses taken as an undergraduate Combined Degree Program student will be applied to the student's undergraduate degree transcript.

Chemical Engineering

JAMES F. ELY, Professor and Head of Department
ANTHONY M. DEAN, W.K. Coors Distinguished Professor
JOHN R. DORGAN, Professor
DAVID W. M. MARR, Professor
J. THOMAS MCKINNON, Professor
RONALD L. MILLER, Professor
E. DENDY SLOAN, Weaver Distinguished Professor
J. DOUGLAS WAY, Professor
ANDREW M. HERRING, Associate Professor
CAROLYN A. KOH, Associate Professor
COLIN A. WOLDEN, Associate Professor
DAVID T. WU, Associate Professor (also Chemistry)
SUMIT AGARWAL, Assistant Professor
MATTHEW W. LIBERATORE, Assistant Professor
TRACY Q. GARDNER, Lecturer
JOHN M. PERSICHETTI, Lecturer
ROBERT J. EVANS, Research Professor
ROBERT D. KNECHT, Research Professor, Director of EPICS
ANGEL ABBUD-MADRID, Research Associate Professor
HANS HEINRICH-CARSTENSEN, Research Associate Professor
SERGEI KISELEV, Research Associate Professor
KELLY T. MILLER, Research Associate Professor
EDWARD P. RIEDEL, Research Associate Professor
GLENN MURRAY, Research Assistant Professor
JOHN OAKEY, Research Assistant Professor
WAYNE ROMONCHUK, Research Assistant Professor
EUN-JAE SHIN, Research Assistant Professor
BERTHE STEMPFER, Research Assistant Professor
PAUL M. THOEN, Research Assistant Professor
ROBERT M. BALDWIN, Professor Emeritus
ANNETTE L. BUNGE, Professor Emeritus
JAMES H. GARY, Professor Emeritus
JOHN O. GOLDEN, Professor Emeritus
ARTHUR J. KIDNAY, Professor Emeritus
VICTOR F. YESAVAGE, Professor Emeritus

Program Description

The field of chemical engineering is extremely broad, and encompasses all technologies and industries where chemical processing is utilized in any form. Students with baccalaureate (B.S.) chemical engineering degrees from CSM can find employment in many and diverse fields, including: advanced materials synthesis and processing, product and process research and development, food and pharmaceutical processing and synthesis, biochemical and biomedical materials and products, microelectronics manufacture, petroleum and petrochemical processing, and process and product design.

The practice of chemical engineering draws from the fundamentals of chemistry, mathematics, and physics. Accordingly, undergraduate students must initially complete a program of study that stresses these three basic fields of science. Chemical engineering coursework blends these three disciplines into a series of engineering fundamentals relating to how materials are produced and processed both in the laboratory and in large industrial-scale facilities. Courses such

as fluid mechanics, heat and mass transport, thermodynamics and reaction kinetics, and chemical process control are at the heart of the chemical engineering curriculum at CSM. In addition, it is becoming increasingly important for chemical engineers to understand how microscopic, molecular-level properties can influence the macroscopic behavior of materials and chemical systems. This somewhat unique focus is first introduced at CSM through the physical and organic chemistry sequences, and the theme is continued and developed within the chemical engineering curriculum via a senior-level capstone course in molecular perspectives. Our undergraduate program at CSM is exemplified by intensive integration of computer-aided molecular simulation and computer-aided process modeling in the curriculum, and by our unique approach to teaching of the unit operations laboratory sequence. The unit operations lab course is offered only in the summer as a six-week intensive “field session”. Here, the fundamentals of heat, mass, and momentum transport and applied thermodynamics are reviewed in a practical, applications-oriented setting. The important subjects of teamwork, critical thinking, and oral and written technical communications skills are also stressed in this course.

Facilities for the study of chemical engineering at the Colorado School of Mines are among the best in the nation. Our modern in-house computer network supports over 50 workstations, and is anchored by an IBM SP-2 parallel supercomputer. Specialized undergraduate laboratory facilities exist for the study of polymer properties, and for reaction engineering and unit operations. In 1992, the department moved into a new \$11 million facility which included both new classroom and office space, as well as high quality laboratories for undergraduate and graduate research. Our honors undergraduate research program is open to highly qualified students, and provides our undergraduates with the opportunity to carry out independent research, or to join a graduate research team. This program has been highly successful and Mines undergraduate chemical engineering students have won several national competitions and awards based on research conducted while pursuing their baccalaureate degree.

The program leading to the degree Bachelor of Science in Chemical Engineering is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Program Educational Objectives (Bachelor of Science in Chemical Engineering)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the Chemical engineering Program at CSM has established the following program educational objectives:

- ◆ Instill in our students a high-quality basic education in chemical engineering fundamentals;

- ◆ Develop the skills required to apply these fundamentals to the synthesis, analysis, and evaluation of chemical engineering processes and systems; and
- ◆ Foster personal development to ensure a lifetime of professional success and an appreciation of the ethical and societal responsibilities of a chemical engineer.

Combined Baccalaureate/Masters Degree Program

The Chemical Engineering Department offers the opportunity to begin work on a Master of Science (with thesis) while completing the requirements of the Bachelor's degree. These combined BS/MS degrees are designed to allow undergraduates engaged in research to apply their experience to an advanced degree. An advantage of the combined BS/MS program is that students may apply 2 classes (6 credit hours) to both their BS and MS degrees. These two classes must be chemical engineering elective courses at the 400-level or higher. The remaining MS curriculum consists of the four core graduate courses (ChEN507, ChEN509, ChEN516, and ChEN518) and 18 thesis credits. It is expected that a student would be able to complete both degrees in 5–5½ years. To take advantage of the combined, program students should be engaged in research and taking graduate coursework during their senior year. For that reason students are expected to apply to the program by the end of their junior year. Students must have a GPA greater than 3.0 to be considered for the program. Interested students are encouraged to get more information from their advisor and/or the current faculty member in charge of Graduate Affairs.

Curriculum

The chemical engineering curriculum is structured according to the goals outlined above. Accordingly, the program of study is organized to include 3 semesters of science and general engineering fundamentals followed by 5 semesters of chemical engineering fundamentals and applications. An optional 'track' system is introduced at the junior year which allows students to structure free electives into one of several specialty applications areas. Courses in the chemical engineering portion of the curriculum may be categorized according to the following general system.

A. Chemical Engineering Fundamentals

The following courses represent the basic knowledge component of the chemical engineering curriculum at CSM.

1. Mass and Energy Balances (ChEN201)
2. Fluid Mechanics (ChEN307)
3. Heat Transfer (ChEN308)
4. Chemical Engineering Thermodynamics (ChEN357)
5. Mass Transfer (ChEN375)
6. Transport Phenomena (ChEN430)

B. Chemical Engineering Applications

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

1. Unit Operations Laboratory (ChEN312 and 313)
2. Reaction Engineering (ChEN418)
3. Process Dynamics and Control (ChEN403)
4. Chemical Engineering Design (ChEN402)
5. Chemical Engineering Technical Electives (one at 400 level)

C. Chemical Engineering Elective Tracks

Students in chemical engineering may elect to structure free electives into a formal Minor program of study (18 hours of coursework), an Area of Special Interest (12 hours) or a Specialty Track in Chemical Engineering (9 hours). Minors and ASIs can be developed by the student in a variety of different areas and programs as approved by the student's advisor and the Heads of the relevant sponsoring academic programs. Specialty tracks in chemical engineering are available in the following areas:

Microelectronics
 Bio Engineering and Life Sciences
 Polymers and Materials
 Molecular Modeling
 Environmental
 Energy
 Business and Economics

Details on recommended courses for each of these tracks can be obtained from the student's academic advisor.

Requirements (Chemical Engineering)

Sophomore Year Fall Semester		lec.	lab.	sem.hrs.
MACS213	Calculus for Scientists & Eng'n's III	4		4
PHGN200	Physics II	3.5	3	4.5
DCGN210	Introduction to Thermodynamics	3		3
CHGN221	Organic Chemistry I	3		3
CHGN223	Organic Chemistry Lab I		3	1
PAGN201	Physical Education III		2	0.5
Total				16
Sophomore Year Spring Semester		lec.	lab.	sem.hrs.
MACS315	Differential Equations	3		3
EBGN201	Principles of Economics	3		3
ChEN201	Mass and Energy Balances	3		3
ChEN202	Chemical Process Principles Lab		1	1
CHGN222	Organic Chemistry II	3		3
EPIC251	Design II	2	3	3
PAGN202	Physical Education IV		2	0.5
Total				16.5
Junior Year Fall Semester		lec.	lab.	sem.hrs.
CHGN351	Physical Chemistry I	3	3	4
ChEN307	Fluid Mechanics	3		3
ChEN357	Chemical. Eng. Thermodynamics	3		3
ChEN358	Chemical. Eng. Thermodynamics Lab		3	1
SYGN200	Human Systems	3		3
Elective*		3		3
Total				17

Junior Year Spring Semester			
	lec.	lab.	sem.hrs.
CHGN353 Physical Chemistry II	3	3	4
ChEN375 Chemical Eng. Mass Transfer	3		3
ChEN308 Chemical Eng. Heat Transfer	3		3
LAIS/EBGN H&SS Elective I	3		3
Elective*	3		3
Total			16
Summer Field Session			
	lec.	lab.	sem.hrs.
ChEN312/313 Unit Operations Laboratory		6	6
Total			6
Senior Year Fall Semester			
	lec.	lab.	sem.hrs.
ChEN418 Reaction Engineering	3		3
ChEN430 Transport Phenomena	3		3
LAIS/EBGN H&SS Elective II	3		3
Electives*	6		6
Total			15
Senior Year Spring Semester			
	lec.	lab.	sem.hrs.
ChEN402 Chemical Engineering Design	3		3
ChEN403 Process Dynamics and Control	3		3
LAIS/EBGN H&SS Elective III	3		3
ChEN421 Engineering Economics	3		3
Elective*	3		3
Total			15
Degree total			134.5

*Two of the electives must be Chemical Engineering courses, one at the 400 level.

Description of Courses

Sophomore Year

ChEN200. COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING Fundamentals of computer programming as applied to the solution of chemical engineering problems. Introduction to Visual Basic, computational methods and algorithm development. Prerequisite: MACS112 or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN201. MATERIAL AND ENERGY BALANCES Introduction to the principles of conservation of mass and energy. Applications to chemical processing systems. Relevant aspects of computer-aided process simulation. Prerequisite: MACS315 (corequisite), DCGN210 or DCGN209 or consent of instructor. Corequisite ChEN202. 3 hours lecture; 3 semester hours.

ChEN202. CHEMICAL PROCESS PRINCIPLES LABORATORY Laboratory measurements dealing with the first and second laws of thermodynamics, calculation and analysis of experimental results, professional report writing. Introduction to computer-aided process simulation. Prerequisites: DCGN210 or DCGN209; corequisites: ChEN201, MACS315 or consent of instructor. 3 hours laboratory; 1 credit hour.

ChEN250. INTRODUCTION TO CHEMICAL ENGINEERING ANALYSIS AND DESIGN. Introduction to chemical process industries and how analysis and design concepts guide the development of new processes and products. Use of simple mathematical models to describe the performance

of common process building blocks including pumps, heat exchangers, chemical reactors, and separators. Prerequisites: Concurrent enrollment in DCGN 210 or consent of instructor. 3 hours lecture; 3 semester hours.

Junior Year

ChEN307. FLUID MECHANICS Theory and application of momentum transport and fluid flow in chemical engineering. Fundamentals of microscopic phenomena and application to macroscopic systems. Relevant aspects of computer-aided process simulation. Prerequisite: ChEN201, MACS315. 3 hours lecture; 3 semester hours.

ChEN308. HEAT TRANSFER Theory and applications of energy transport: conduction, convection and radiation. Fundamentals of microscopic phenomena and application to macroscopic systems. Relevant aspects of computer-aided process simulation. Prerequisite: ChEN201, ChEN307, MACS315, or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN312/313. UNIT OPERATIONS LABORATORY Field Session (WI) Principles of mass, energy, and momentum transport as applied to laboratory-scale processing equipment. Written and oral communications skills. Aspects of group dynamics, teamwork, and critical thinking. Prerequisite: ChEN201, ChEN307, ChEN308, ChEN357, ChEN375 6 hours lab; 6 semester hours.

ChEN340. COOPERATIVE EDUCATION Cooperative work/education experience involving employment of a chemical engineering nature in an internship spanning at least one academic semester. Prerequisite: consent of instructor. 1 to 3 semester hours.

ChEN350. HONORS UNDERGRADUATE RESEARCH Scholarly research of an independent nature. Prerequisite: junior standing, consent of instructor. 1 to 3 semester hours.

ChEN351. HONORS UNDERGRADUATE RESEARCH Scholarly research of an independent nature. Prerequisite: junior standing, consent of instructor. 1 to 3 semester hours.

ChEN357. CHEMICAL ENGINEERING THERMODYNAMICS Fundamentals of thermodynamics for application to chemical engineering processes and systems. Phase and reaction equilibria. Relevant aspects of computer-aided process simulation. Integrated laboratory experiments. Prerequisite: DCGN210 or DCGN209, ChEN201, MACS315, or consent of instructor. Corequisite: ChEN358. 3 hours lecture; 3 semester hours.

ChEN358. CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY Laboratory measurement, calculation and analysis of physical properties, phase equilibria and reaction equilibria and their application to chemical engineering. Relevant aspects of computer-aided simulation. Prerequisites: DCGN210 or DCGN209, ChEN201, MACS315, or consent of instructor. Corequisite: ChEN357. 3 hours laboratory; 1 semester hour.

ChEN375. MASS TRANSFER Fundamentals of stage-wise and diffusional mass transport with applications to chemical engineering systems and processes. Relevant aspects of computer-aided process simulation. Prerequisite: ChEN201, ChEN357, or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN398. SPECIAL TOPICS IN CHEMICAL ENGINEERING Topical courses in chemical engineering of special interest. Prerequisite: consent of instructor. 1 to 6 semester hours.

ChEN399. INDEPENDENT STUDY Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: consent of instructor and department head, submission of "Independent Study" form to CSM Registrar. 1 to 6 semester hours.

Senior Year

ChEN402. CHEMICAL ENGINEERING DESIGN (WI) Advanced computer-aided process simulation and process optimization. Prerequisite: ChEN307, ChEN308, ChEN357, ChEN375, or consent of instructor. Co-requisite: ChEN418, ChEN421. 3 hours lecture; 3 semester hours.

ChEN403. PROCESS DYNAMICS AND CONTROL Mathematical modeling and analysis of transient systems. Applications of control theory to response of dynamic chemical engineering systems and processes. Prerequisite: ChEN201, ChEN307, ChEN308, ChEN375, MACS315, or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN408. NATURAL GAS PROCESSING Application of chemical engineering principles to the processing of natural gas. Emphasis on using thermodynamics and mass transfer operations to analyze existing plants. Relevant aspects of computer-aided process simulation. Prerequisites: CHGN221, ChEN201, ChEN307, ChEN308, ChEN357, ChEN375, or consent of instructor. 3 hours lecture, 3 semester hours.

ChEN409. PETROLEUM PROCESSES Application of chemical engineering principles to petroleum refining. Thermodynamics and reaction engineering of complex hydrocarbon systems. Relevant aspects of computer-aided process simulation for complex mixtures. Prerequisite: CHGN221, ChEN201, ChEN357, ChEN375, or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN415/CHGN430/MLGN530. POLYMER SCIENCE AND TECHNOLOGY Chemistry and thermodynamics of polymers and polymer solutions. Reaction engineering of polymerization. Characterization techniques based on solution properties. Materials science of polymers in varying physical states. Processing operations for polymeric materials and use in separations. Prerequisite: CHGN221, MACS315, ChEN357, or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN416. POLYMER ENGINEERING AND TECHNOLOGY Polymer fluid mechanics, polymer rheological response, and polymer shape forming. Definition and measurement of material properties. Interrelationships between response functions and correlation of data and material response. Theoretical approaches for prediction of polymer properties. Processing operations for polymeric materials; melt and flow instabilities. Prerequisite: ChEN307, MACS315, or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN418. REACTION ENGINEERING (WI) Applications of the fundamentals of thermodynamics, physical chemistry, and organic chemistry to the engineering of reactive processes. Reactor design; acquisition and analysis of rate data; heterogeneous catalysis. Relevant aspects of computer-aided process simulation. Prerequisite: ChEN201, ChEN307, ChEN308, ChEN357, MACS315, CHGN221, CHGN351, or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN420. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING Formulation and solution of chemical engineering problems using exact analytical solution methods. Set-up and solution of ordinary and partial differential equations for typical chemical engineering systems and transport processes. Prerequisite: MACS315, ChEN201, ChEN307, ChEN308, ChEN375, or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN421. ENGINEERING ECONOMICS Economic analysis of engineering processes and systems. Interest, annuity, present value, depreciation, cost accounting, investment accounting and financing of engineering enterprises along with taxation, market evaluation and break-even analysis. Prerequisite: consent of instructor. 3 hours lecture; 3 semester hours.

ChEN430. TRANSPORT PHENOMENA Theory and chemical engineering applications of momentum, heat, and mass transport. Set up and solution of problems involving equations of motion and energy. Prerequisite: ChEN307, ChEN308, ChEN357, ChEN375, MACS315, or consent of instructor. 3 hours lecture; 3 semester hours.

ChEN435/PHGN435. INTERDISCIPLINARY MICRO-ELECTRONICS PROCESSING LABORATORY (II) Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisites: Senior standing in PHGN, ChEN, MTGN, or EGGN. Consent of instructor. Due to lab space the enrollment is limited to 20 students. 1.5 hours lecture, 4 hours lab; 3 semester hours.

ChEN440. MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING Applications of statistical and quantum mechanics to understanding and prediction of equilibrium and transport properties and processes. Relations between microscopic properties of materials and systems to macroscopic behavior. Prerequisite: ChEN307, ChEN308, ChEN357, ChEN375, CHGN351 and 353, CHGN221 and 222, MACS315, or consent of instructor. 3 hours lecture; 3 semester hours

ChEN450. HONORS UNDERGRADUATE RESEARCH Scholarly research of an independent nature. Prerequisite: senior standing, consent of instructor. 1 to 3 semester hours.

ChEN451. HONORS UNDERGRADUATE RESEARCH Scholarly research of an independent nature. Prerequisite: senior standing, consent of instructor. 1 to 3 semester hours.

ChEN498. SPECIAL TOPICS IN CHEMICAL ENGINEERING Topical courses in chemical engineering of special interest. Prerequisite: consent of instructor; 1 to 6 semester hours.

ChEN499. INDEPENDENT STUDY Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: consent of instructor and department head, submission of "Independent Study" form to CSM Registrar. 1 to 6 semester hours.

Chemistry and Geochemistry

PAUL W. JAGODZINSKI, Professor
DANIEL M. KNAUSS, Professor
DONALD L. MACALADY, Professor
PATRICK MACCARTHY, Professor
KENT J. VOORHEES, Professor
SCOTT W. COWLEY, Associate Professor
MARK E. EBERHART, Associate Professor
KEVIN W. MANDERNACK, Associate Professor (also Geology & Geological Engineering)
JAMES F. RANVILLE, Associate Professor
E. CRAIG SIMMONS, Associate Professor
BETTINA M. VOELKER, Associate Professor
KIM R. WILLIAMS, Associate Professor
DAVID T. WU, Associate Professor (also Chemical Engineering)
STEPHEN G. BOYES, Assistant Professor
STEVEN F. DEC, Lecturer
BRAD J. HERRICK, Lecturer
RAMON E. BISQUE, Professor Emeritus
STEPHEN R. DANIEL, Professor Emeritus
DEAN W. DICKERHOOF, Professor Emeritus
KENNETH W. EDWARDS, Professor Emeritus
GEORGE H. KENNEDY, Professor Emeritus
RONALD W. KLUSMAN, Professor Emeritus
DONALD LANGMUIR, Professor Emeritus
GEORGE B. LUCAS, Professor Emeritus
MICHAEL J. PAVELICH, Professor Emeritus
MAYNARD SLAUGHTER, Professor Emeritus
THOMAS R. WILDEMAN, Professor Emeritus
JOHN T. WILLIAMS, Professor Emeritus
ROBERT D. WITTERS, Professor Emeritus
CHARLES W. STARKS, Associate Professor Emeritus

Program Description

Chemistry provides fundamental knowledge critical to satisfying many of society's needs: feeding and clothing and housing the world's people, finding and using sources of energy, improving health care, ensuring national security, and protecting the environment. The programs of the Chemistry and Geochemistry Department are designed to educate professionals for the varied career opportunities this central scientific discipline affords. The curricula are therefore founded in rigorous fundamental science complemented by application of these principles to the minerals, energy, materials, or environmental fields. For example, a specific B.S. curricular track emphasizing environmental chemistry is offered along with a more flexible track which can be tailored to optimize preparation consistent with students' career goals. Those aspiring to enter Ph.D. programs in chemistry are encouraged to include undergraduate research beyond the minimum required among their elective hours. Others interested in industrial chemistry choose area of special interest courses in chemical engineering or metallurgy, for example. A significant number of students complete degrees in both chemistry and chemical engineering as an excellent preparation for industrial careers.

The instructional and research laboratories located in Coolbaugh Hall contain extensive instrumentation for: gas chromatography (GC), high-performance liquid chromatography (HPLC), ion chromatography (IC), supercritical-fluid chromatography (SFC), inductively-coupled-plasma-atomic emission spectroscopy (ICP-AES) field-flow fractionation (FFF), mass spectrometry (MS, GC/MS, GC/MS/MS, PY/MS, PY/GC/MS, SFC/MS, MALDI-TOF), nuclear magnetic resonance spectrometry (solids and liquids), infrared spectrophotometry (FTIR), visible-ultraviolet spectrophotometry, microscopy, X-ray photoelectron spectrometry (XPS), and thermogravimetric analysis (TGA).

Program Educational Objectives (Bachelor of Science in Chemistry)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the B.S. curricula in chemistry are designed to:

- ◆ Impart mastery of chemistry fundamentals;
- ◆ Develop ability to apply chemistry fundamentals in solving open-ended problems;
- ◆ Impart knowledge of and ability to use modern tools of chemical analysis and synthesis;
- ◆ Develop ability to locate and use pertinent information from the chemical literature;
- ◆ Develop ability to interpret and use experimental data for chemical systems;
- ◆ Develop ability to effectively communicate in both written and oral formats;
- ◆ Prepare students for entry to and success in professional careers;
- ◆ Prepare students for entry to and success in graduate programs; and
- ◆ Prepare students for responsible contribution to society.

Curriculum

The B.S. chemistry curricula, in addition to the strong basis provided by the common core, contain three components: chemistry fundamentals, laboratory and communication skills, and applications courses.

Chemistry fundamentals

- ◆ Analytical chemistry - sampling, method selection, statistical data analysis, error sources, interferences, theory of operation of analytical instruments (atomic and molecular spectroscopy, mass spectrometry, magnetic resonance spectrometry, chromatography and other separation methods, electroanalytical methods, and thermal methods), calibration, standardization, stoichiometry of analysis, equilibrium and kinetics principles in analysis.
- ◆ Inorganic chemistry - atomic structure and periodicity, crystal lattice structure, molecular geometry and bonding (VSEPR, Lewis structures, VB and MO theory, bond energies and lengths), metals structure and properties, acid-base theories, main-group element chemistry, coordination chemistry, term symbols, ligand field theory, spectra and magnetism of complexes, organometallic chemistry.
- ◆ Organic chemistry - bonding and structure, structure-physical property relationships, reactivity-structure relationships, reaction mechanisms (nucleophilic and electrophilic substitution, addition, elimination, radical reactions, rearrangements, redox reactions, photochemical reactions, and metal-mediated reactions), chemical kinetics, catalysis, major classes of compounds and their reactions, design of synthetic pathways.
- ◆ Physical chemistry - thermodynamics (energy, enthalpy, entropy, equilibrium constants, free energy, chemical potential, non-ideal systems, standard states, activity, phase rule, phase equilibria, phase diagrams), electrochemistry, kinetic theory (Maxwell-Boltzmann distribution, collision frequency, effusion, heat capacity, equipartition of energy), kinetics (microscopic reversibility, relaxation processes, mechanisms and rate laws, collision and absolute rate theories), quantum mechanics (Schrödinger equations, operators and matrix elements, particle-in-a-box, simple harmonic oscillator, rigid rotor, angular momentum, hydrogen atom, hydrogen wave functions, spin, Pauli principle, LCAO method), spectroscopy (dipole selection rules, rotational spectra, term symbols, atomic and molecular electronic spectra, magnetic spectroscopy, Raman spectroscopy, multiphoton selection rules, lasers), statistical thermodynamics (ensembles, partition functions, Einstein crystals, Debye crystals), group theory, surface chemistry, X-ray crystallography, electron diffraction, dielectric constants, dipole moments.

Laboratory and communication skills

- ◆ Analytical methods - gravimetry, titrimetry, sample dissolution, fusion, quantitative spectrophotometry, GC, HPLC, GC/MS, potentiometry, AA, ICP-AES
- ◆ Synthesis techniques - batch reactor assembly, inert-atmosphere manipulations, vacuum line methods, high-temperature methods, high-pressure methods, distillation, recrystallization, extraction, sublimation, chromatographic purification, product identification
- ◆ Physical measurements - refractometry, viscometry, colligative properties, FTIR, NMR
- ◆ Information retrieval - Chemical Abstracts, CA on-line, CA registry numbers, Beilstein, Gmelin, handbooks, organic syntheses, organic reactions, inorganic syntheses, primary sources, ACS Style Guide
- ◆ Reporting - lab notebook, experiment and research reports, technical oral reports
- ◆ Communication - scientific reviews, seminar presentations

Applications

- ◆ Area of special interest courses - application of chemistry fundamentals in another discipline; e.g. chemical engineering, environmental science, materials science
- ◆ Internship - summer or semester experience in an industrial or governmental organization working on real-world problems
- ◆ Undergraduate research-open-ended problem solving in the context of a research project

Degree Requirements (Chemistry)

The B.S. curricula in chemistry are outlined below. The restrictions specific to the environmental chemistry track are labeled (env) while those specific to the other track are labeled (chm); those common to both tracks bear no label. In the environmental track the area of special interest must be in Environmental Science and Engineering (ESGN) (see page 55).

Sophomore Year Fall Semester	lec.	lab.	sem.hrs.
MACS213 Calculus for Scientists & Engr's III	4		4
PHGN200 Physics II	3.5	3	4.5
DCGN209 Introduction to Thermodynamics	3		3
CHGN221 Organic Chemistry I	3		3
CHGN223 Organic Chemistry I Lab		3	1
PAGN201 Physical Education III		2	0.5
Total			16

Sophomore Year Spring Semester	lec.	lab.	sem.hrs.
CHGN222 Organic Chemistry II	3		3
CHGN224 Organic Chemistry II Lab		3	1
Technical Elective [#]	3		3
MACS315 Differential Equations	3		3
CHGN335 Instrumental Analysis	3		3
CHGN201 Thermodynamics Laboratory		3	1
EPIC251 Design II	2	3	3
PAGN202 Physical Education IV		2	0.5
Total			17.5

Junior Year Fall Semester	lec.	lab.	sem.hrs.
SYGN200 Human Systems	3		3
CHGN428 Biochemistry	3		3
CHGN336 Analytical Chemistry	3		3
CHGN337 Analytical Chemistry Laboratory		3	1
CHGN351 Physical Chemistry I	3	3	4
Area of Special Interest Elective (chm)**	3		3
ESGN - Environmental Elective (env)**	3		3
Total			17

**specialty restrictions

Junior Year Spring Semester	lec.	lab.	sem.hrs.
CHGN353 Physical Chemistry II	3	3	4
CHGN341 Descriptive Inorganic Chemistry	3		3
CHGN323 Qualitative Organic Analysis	1	3	2
CHGN395 Introduction to Undergraduate Research	3		1
EBGN201 Principles of Economics	3		3
Area of Special Interest Elective (chm)**	3		3
Free elective	3		3
LAIS/EBGN H&SS Elective I	3		3
Total			19

**specialty restrictions

Junior-Senior Year Summer Field Session	lec.	lab.	sem.hrs.
CHGN490 Synthesis & Characterization		18	6
Total			6

Senior Year Fall Semester	lec.	lab.	sem.hrs.
CHGN495 Research		9	3
Area of Special Interest Elective (chm)**	3		3
ESGN Area of Special Interest (env)**	6		6
LAIS/EBGN H&SS Cluster Elective II	3		3
CHGN401 Theoretical Inorganic Chem. (chm)**	3		3
Free elective (chm)**	3		3
Total			15

**specialty restrictions

Senior Year Spring Semester	lec.	lab.	sem.hrs.
CHGN495 Undergraduate Research		6	2
CHGN410 Surface Chemistry (env)**	3		3
Area of Special Interest Elective (chm)**	3		3
ESGN Area of Special Interest (env)**	3		3
LAIS/EBGN H&SS Cluster Elective III	3		3
CHGN403 Environmental Chemistry (env)**	3		3
Free elective (chm)**	3		3
Free elective	3		3
Total			14

Degree Total 137.5

Possible electives that will be recommended to students are:

SYGN202; SYGN203; ChEN201; PHGN300; EBG305, EBG306, EBG310, EBG311, EBG312; ESGN201/BELS301; ESGN353; GEOL201, 210, 212; MNGN210; PEGN102; CHGN462

Chemistry Minor and ASI Programs

No specific course sequences are suggested for students wishing to include chemistry minors or areas of special interest in their programs. Rather, those students should consult with the CHGC department head (or designated faculty member) to design appropriate sequences.

Description of Courses

CHGN111. INTRODUCTORY CHEMISTRY (S) Introductory college chemistry. Elementary atomic structure and the periodic chart, chemical bonding, properties of common elements and their compounds, and stoichiometry of chemical reactions. Must not be used for elective credit. 3 hours lecture and recitation; 3 semester hours.

CHGN121. PRINCIPLES OF CHEMISTRY I (I, II) Study of matter and energy based on atomic structure, correlation of properties of elements with position in periodic chart, chemical bonding, geometry of molecules, phase changes, stoichiometry, solution chemistry, gas laws, and thermochemistry. 3 hours lecture, 3 hours lab; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1.

CHGN124. PRINCIPLES OF CHEMISTRY II (I, II, S) Continuation of CHGN121 concentrating on chemical kinetics, thermodynamics, electrochemistry, organic nomenclature, and chemical equilibrium (acid-base, solubility, complexation, and redox). Prerequisite: Credit in CHGN121. 3 hours lecture; 3 semester hours.

CHGN126. QUANTITATIVE CHEMICAL MEASUREMENTS (I, II, S) Experiments emphasizing quantitative chemical measurements. Prerequisite: Credit in or concurrent enrollment in CHGN124. 3 hours lab; 1 semester hour.

CHGN198. SPECIAL TOPICS IN CHEMISTRY (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

CHGN199. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

CHGN201. CHEMICAL THERMODYNAMICS LABORATORY (II) Experiments in determining enthalpy, entropy, free energy, equilibrium constants, reaction rates, colligative properties. Prerequisites DCGN209 or concurrent enrollment. 3 hours lab; 1 semester hour.

CHGN221. ORGANIC CHEMISTRY I (I) Structure, properties, and reactions of the important classes of organic compounds, introduction to reaction mechanisms. Prerequisites: CHGN124, CHGN126. 3 hours lecture; 3 semester hours.

CHGN223. ORGANIC CHEMISTRY I LABORATORY (I,II) Laboratory exercises including purification techniques, synthesis, and characterization. Experiments are designed to support concepts presented in the CHGN221. Students are introduced to Green Chemistry principles and methods of synthesis and the use of computational software. Prerequisites: CHGN221 or concurrent enrollment. 3 hours laboratory, 1 semester hour.

CHGN222. ORGANIC CHEMISTRY II (II) Continuation of CHGN221. Prerequisites: CHGN221, CHGN223 or concurrent enrollment. 3 hours lecture; 3 semester hours.

CHGN224. ORGANIC CHEMISTRY II LABORATORY (II) Laboratory exercises using more advanced synthesis techniques. Experiments are designed to support concepts presented in CHGN222. Prerequisites: CHGN221, CHGN223, and CHGN222 or concurrent enrollment. 3 hours laboratory, 1 semester hour.

CHGN298. SPECIAL TOPICS IN CHEMISTRY (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

CHGN299. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

CHGN323. QUALITATIVE ORGANIC ANALYSIS (II) Identification, separation and purification of organic compounds including use of modern physical and instrumental methods. Prerequisite: CHGN222, CHGN224. 1 hour lecture; 3 hours lab; 2 semester hours.

CHGN335. INSTRUMENTAL ANALYSIS (II) Principles of AAS, AES, Visible-UV, IR, NMR, XRF, XRD, XPS, electron, and mass spectroscopy; gas and liquid chromatography; data interpretation. Prerequisite: DCGN209, MACS112. 3 hours lecture; 3 semester hours.

CHGN336. ANALYTICAL CHEMISTRY (I) Theory and techniques of gravimetry, titrimetry (acid-base, complexometric, redox, precipitation), electrochemical analysis, chemical separations; statistical evaluation of data. Prerequisite: DCGN209, CHGN335. 3 hours lecture; 3 semester hours.

CHGN337. ANALYTICAL CHEMISTRY LABORATORY (I) (WI) Laboratory exercises emphasizing sample preparation and instrumental methods of analysis. Prerequisite: CHGN335, CHGN336 or concurrent enrollment. 3 hours lab; 1 semester hour.

CHGN340. COOPERATIVE EDUCATION (I, II, S) Supervised, full-time, chemistry-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

CHGN341. DESCRIPTIVE INORGANIC CHEMISTRY (II) The chemistry of the elements and periodic trends in reactivity discussed in relation to the preparation and use of inorganic chemicals in industry and the environment. Prerequisite: CHGN222, DCGN209. 3 hours lecture; 3 semester hours.

CHGN351. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I (I) A study of chemical systems from a molecular physical chemistry perspective. Includes an introduction to quantum mechanics, atoms and molecules, spectroscopy, bonding and symmetry, and an introduction to modern computational chemistry. Prerequisite: CHGN124, DCGN209, MACS315, PHGN200. 3 hours lecture; 3 hours laboratory; 4 semester hours.

CHGN353. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II (II) A continuation of CHGN351. Includes statistical thermodynamics, chemical kinetics, chemical reaction mechanisms, electrochemistry, and selected additional topics. Prerequisite: CHGN351. 3 hours lecture; 3 hours laboratory; 4 semester hours.

CHGN395. INTRODUCTION TO UNDERGRADUATE RESEARCH (I, II, S) (WI) Introduction to Undergraduate Research is designed to prepare students to pursue their senior research projects prior to enrollment in CHGN495

(Undergraduate Research). Students will attend lectures and research presentations, the student, in consultation with their research advisor, will select a research area, perform literature research, design a research project and prepare a research proposal. Prerequisites: Completion of the chemistry curriculum through the Fall semester of the junior year or permission of the department head. Credit: 1 semester hour.

CHGN398. SPECIAL TOPICS IN CHEMISTRY (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

CHGN399. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

CHGN401. THEORETICAL INORGANIC CHEMISTRY (II) Periodic properties of the elements. Bonding in ionic and metallic crystals. Acid-base theories. Inorganic stereochemistry. Nonaqueous solvents. Coordination chemistry and ligand field theory. Prerequisite: CHGN341 or consent of instructor. 3 hours lecture; 3 semester hours.

CHGN402. BONDING THEORY AND SYMMETRY (II) Introduction to valence bond and molecular orbital theories, symmetry; introduction to group theory; applications of group theory and symmetry concepts to molecular orbital and ligand field theories. Prerequisite: CHGN341 or consent of instructor. 3 hours lecture; 3 semester hours.

CHGN/ESGN403. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY (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. Prerequisites: SYGN101, DCGN209, CHGN222. 3 hours lecture; 3 semester hours.

CHGN410/MLGN510. SURFACE CHEMISTRY (II) Introduction to colloid systems, capillarity, surface tension and contact angle, adsorption from solution, micelles and microemulsions, the solid/gas interface, surface analytical techniques, van der Waal forces, electrical properties and colloid stability, some specific colloid systems (clays, foams and emulsions). Students enrolled for graduate credit in MLGN510 must complete a special project. Prerequisite: DCGN209 or consent of instructor. 3 hours lecture; 3 semester hours.

CHGN422. POLYMER CHEMISTRY LABORATORY (I) Prerequisites: CHGN221, CHGN223. 3 hours lab; 1 semester hour.

CHGN428. INTRODUCTORY BIOCHEMISTRY (I) Introductory study of the major molecules of biochemistry-amino acids, proteins, enzymes, nucleic acids, lipids, and saccharides- their structure, chemistry, biological function, and biosynthesis. Stresses bioenergetics and the cell as a biological unit of organization. Discussion of classical genetics, molecular genetics, and protein synthesis. Prerequisite: CHGN221 or permission of instructor. 3 hours lecture; 3 semester hours.

CHGN430/MLGN530. INTRODUCTION TO POLYMER SCIENCE (I) An introduction to the chemistry and physics of macromolecules. Topics include the properties and statistics of polymer solutions, measurements of molecular weights, molecular weight distributions, properties of bulk polymers, mechanisms of polymer formation, and properties of thermosets and thermoplasts including elastomers. Prerequisite: CHGN221 or permission of instructor. 3 hour lecture, 3 semester hours.

CHGN462. MICROBIOLOGY AND THE ENVIRONMENT This course will cover the basic fundamentals of microbiology, such as structure and function of prokaryotic versus eukaryotic cells; viruses; classification of microorganisms; microbial metabolism, energetics, genetics, growth and diversity, microbial interactions with plants, animals, and other microbes. Additional topics covered will include various aspects of environmental microbiology such as global biogeochemical cycles, bioleaching, bioremediation, and wastewater treatment. Prerequisite: Consent of instructor 3 hours lecture, 3 semester hours. Offered in alternate years.

CHGN475. COMPUTATIONAL CHEMISTRY (II) This class provides a survey of techniques of computational chemistry, including quantum mechanics (both Hartree-Fock and density functional approaches) and molecular dynamics. Emphasis is given to the integration of these techniques with experimental programs of molecular design and development. Prerequisites: CHGN351, CHGN401. 3 hours lecture; 3 semester hours.

CHGN490. SYNTHESIS AND CHARACTERIZATION (WI) Advanced methods of organic and inorganic synthesis; high-temperature, high-pressure, inert-atmosphere, vacuum-line, and electrolytic methods. Prerequisites: CHGN323, CHGN341. 6-week summer field session; 6 semester hours.

CHGN495. UNDERGRADUATE RESEARCH (I, II, S) (WI) Individual research project under direction of a member of the Departmental faculty. Prerequisites: selection of a research topic and advisor, preparation and approval of a research proposal, completion of chemistry curriculum through the junior year or permission of the department head. Variable credit; 1 to 5 credit hours.

CHGN497. INTERNSHIP (I, II, S) Individual internship experience with an industrial, academic, or governmental host supervised by a Departmental faculty member. Prerequisites: Completion of chemistry curriculum through the junior year or permission of the department head. Variable credit; 1 to 6 credit hours.

CHGN498. SPECIAL TOPICS IN CHEMISTRY (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

CHGN499. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Economics and Business

RODERICK G. EGGERT, Professor and Division Director
JOHN T. CUDDINGTON, William J. Coulter Professor
CAROL A. DAHL, Professor
GRAHAM A. DAVIS, Professor
MICHAEL R. WALLS, Professor
ALEXANDRA M. NEWMAN, Associate Professor
EDWARD J. BALISTRERI, Assistant Professor
CIGDEM Z. GURGUR, Assistant Professor
MICHAEL B. HEELEY, Assistant Professor
IRINA KHINDANOVA, Assistant Professor
YADVIGA V. SEMIKOLENOVA, Assistant Professor
JOHN M. STERMOLE, Lecturer
ANN DOZORETZ, Instructor
FRANKLIN J. STERMOLE, Professor Emeritus
JOHN E. TILTON, University Emeritus Professor
ROBERT E. D. WOOLSEY, Professor Emeritus

Program Description

The economy is becoming increasingly global and dependent on advanced technology. In such a world, private companies and public organizations need leaders and managers who understand economics and business, as well as science and technology.

Programs in the Division of Economics and Business are designed to bridge the gap that often exists between economists and managers, on the one hand, and engineers and scientists, on the other. All CSM undergraduate students are introduced to economic principles in a required course, and many pursue additional course work in minor programs or elective courses. The courses introduce undergraduate students to economic and business principles so that they will understand the economic and business environments, both national and global, in which they will work and live.

In keeping with the mission of the Colorado School of Mines, the Division of Economics and Business offers a Bachelor of Science in Economics. Most economics degrees at other universities are awarded as a Bachelor of Arts, with a strong liberal arts component. Our degree, the only one of its kind in Colorado, is grounded in mathematics, engineering and the sciences. We graduate technologically literate economists with quantitative economics and business skills that give them a competitive advantage in today's economy.

Economics majors have a range of career options following their undergraduate studies. Some pursue graduate degrees in economics, business, or law. Others begin careers as managers, economic advisors, and financial officers in business or government, often in organizations that deal with engineering, applied science, and advanced technology.

Program Educational Objectives (Bachelor of Science in Economics)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the educational objectives

of the undergraduate program in economics and business are:

To provide students with a strong foundation in economic theory and analytical techniques, taking advantage of the mathematical and quantitative abilities of CSM undergraduate students; and

To prepare students for the work force, especially in organizations in CSM's areas of traditional strength (engineering, applied science, mathematics and computer science), and for graduate school, especially in economics, business, and law.

Curriculum

Within the major, students can choose a special concentration in Global Business or Technology. If students do not choose one of these options, they will complete the (default) Economics and Business option. All economics majors take forty-five percent of their courses in math, science, and engineering, including the same core required of all CSM undergraduates. Students take another forty percent of their courses in economics, business, and the humanities and social sciences more generally. The remaining fifteen percent of the course work can come from any field. Many students complete minor programs in a technical field, such as computer science, engineering, geology, or environmental science. A number of students pursue double majors.

To complete the economics major, students must take 39 hours of 300 and 400 level economics and business courses. Of these, 18 hours must be at the 400 level. At least 30 of the required 39 hours must be taken in residence in the home department. For students participating in an approved foreign study program, up to 19 hours of the 30 hours in residence requirement may be taken abroad.

Degree Requirements in Economics Economics and Business Option (default)

	lec.	lab.	sem.hrs.
Sophomore Year Fall Semester			
EBGN311 Principles of Microeconomics*	3		3
PHGN200 Physics II	3.5	3	4.5
MACS213 Calc. for Scientists & Engineers III	4		4
MACS323 Probability and Statistics	3		3
EPICS251 or EPICS252 Design II	2	3	3
PAGN201 Physical Education III	2		0.5
Total			18
Sophomore Year Spring Semester			
EBGN312 Principles of Macroeconomics*	3		3
MACS315 Differential Equations	3		3
SYGN200 Human Systems	3		3
PAGN202 Physical Education IV	2		0.5
Free Electives	6		6
Total			15.5
Junior Year Fall Semester			
EBGN325 Operations Research Methods	3		3
EBGN390 Econometrics	3		3
EBGN411 Intermediate Microeconomics	3		3
EBGN412 Intermediate Macroeconomics	3		3
MACS332 Linear Algebra	3		3
LAIS H&SS Cluster Elective I	3		3
Total			18

	lec.	lab.	sem.hrs.
Junior Year Spring Semester			
EBGN321 Engineering Economics	3		3
EBGN409 Math Econ. or EBGN455 Lin. Prog.**	3		3
EBGN Elective II	3		3
LAIS Restricted Elective I	3		3
LAIS H&SS Cluster Elective II	3		3
Free Elective	3		3
Total			18
Summer Field Session			
EBGN402 Field Session	3		3
Total			3
Senior Year Fall Semester			
EBGN Elective II	3		3
EBGN Elective III	3		3
LAIS Restricted Elective II	3		3
LAIS H&SS Cluster Elective III	3		3
Free Elective	3		3
Total			15
Senior Year Spring Semester			
EBGN Elective IV	3		3
LAIS Restricted Elective III	3		3
Free Electives	9		9
Total			15
Degree Total			135.5

*Students who complete the EBGN311/312 sequence are not required to take EBGN201. For students pursuing a major in economics, EBGN201 is not a substitute for either EBGN311 or EBGN312.

**Students must take either EBGN409 or EBGN455.

Technology Option

	lec.	lab.	sem.hrs.
Sophomore Year Fall Semester			
Same courses as in default option above.			
Total			18
Sophomore Year Spring Semester			
Same courses as in default option above.			
Total			15.5
Junior Year Fall Semester			
EBGN325 Operations Research	3		3
EBGN390 Econometrics	3		3
EBGN411 Intermediate Microeconomics	3		3
EBGN412 Intermediate Macroeconomics	3		3
MACS332 Linear Algebra	3		3
LAIS H&SS Cluster Elective I	3		3
Total			18
Junior Year Spring Semester			
EBGN321 Engineering Economics	3		3
EBGN409 Math Econ. or EBGN455 Lin. Prog.**	3		3
EBGN Technology Elective I	3		3
Technology Elective I	3		3
LAIS H&SS Cluster Elective II	3		3
Free Elective	3		3
Total			18
Summer Field Session			
EBGN402 Field Session	3		3
Total			3

Senior Year Fall Semester			
	lec.	lab.	sem.hrs.
EBGN Technology Elective II	3		3
EBGN Technology Elective III	3		3
LAIS Technology Elective II	3		3
LAIS H&SS Cluster Elective III	3		3
Free Electives	3		3
Total			15

Senior Year Spring Semester			
	lec.	lab.	sem.hrs.
EBGN Technology Elective IV	3		3
LAIS Technology Elective III	3		3
Free Electives	9		9
Total			15

Degree Total 135.5

** Students must take either EBG409 or EBG455.

Global Business Option

Sophomore Year Fall Semester			
	lec.	lab.	sem.hrs.
Same courses as in default option above.			
Total			18

Sophomore Year Spring Semester			
	lec.	lab.	sem.hrs.
Same courses as in default option above.			
Total			15.5

Junior Year Fall Semester			
	lec.	lab.	sem.hrs.
EBGN325 Operations Research	3		3
EBGN390 Econometrics	3		3
EBGN411 Intermediate Microeconomics	3		3
EBGN412 Intermediate Macroeconomics	3		3
MACS332 Linear Algebra	3		3
LAIS H&SS Cluster Elective I	3		3
Total			18

Junior Year Spring Semester			
	lec.	lab.	sem.hrs.
EBGN321 Engineering Economics	3		3
EBGN409 Math Econ or EBGN 455 Lin. Prog.**	3		3
EBGN Global Business Elective II	3		3
LIFL Foreign Language I*	3		3
LAIS H&SS Cluster Elective II	3		3
Free Elective	3		3
Total			18

Summer Field Session			
	lec.	lab.	sem.hrs.
EBGN402 Field Session	6		3
Total			3

Senior Year Fall Semester			
	lec.	lab.	sem.hrs.
EBGN Global Business Elective II	3		3
EBGN Global Business Elective III	3		3
LAIS Global Business Elective I	3		3
LIFL Foreign Language II*	3		3
LAIS H&SS Cluster Elective III	3		3
Total			15

Senior Year Spring Semester			
	lec.	lab.	sem.hrs.
EBGN Global Business Elective IV	3		3
LAIS Global Business Elective II	3		3
Free Electives	9		9
Total			15

Degree Total 135.5

*Must be in same language.

**Students must take either EBG409 or EBG455.

Electives for the Economics Major Listed by Specialization

Economics and Business Specialization (default)

Economics and Business specialization students take 12 hours from the following list of EBG409 electives, of which at least 3 hours must be a 400-level course that has EBG411 and/or EBG412 as prerequisites.

EBGN304 Personal Finance
EBGN305 Financial Accounting
EBGN306 Managerial Accounting
EBGN310 Environmental and Resource Economics
EBGN314 Principles of Management
EBGN315 Business Strategy
EBGN320 Economics and Technology
EBGN330 Energy Economics
EBGN342 Economic Development
EBGN345 Principles of Corporate Finance
EBGN401 History of Economic Thought
EBGN409 Mathematical Economics [†]
EBGN441 International Trade
EBGN445 International Business Finance
EBGN455 Linear Programming [†]
EBGN495 Economic Forecasting
EBGN5XX ^{††}

[†]Only counts if not taken as part of the EBG409 core.

^{††}Seniors with at least a 2.50 cumulative GPA may take a 500-level course with the consent of their department and the Dean of Graduate Studies.

Economics and Business specialization students take 9 hours from the following list of LAIS restricted electives. Courses used to satisfy the H&SS cluster requirements cannot be double counted.

LICM301 Professional Oral Communication
LICM306 Selected Topics in Written Communication
LAIS285 Introduction to Law and Legal Systems
LAIS335 International Political Economy of Latin America
LAIS337 International Political Economy of Asia
LAIS339 International Political Economy of the Middle East
LAIS341 International Political Economy of Africa
LAIS345 International Political Economy
LAIS435 Latin American Development
LAIS436 Hemispheric Integration in the Americas
LAIS437 Asian Development
LAIS441 African Development
LAIS442 Natural Resources and War in Africa
LAIS446 Globalization
LAIS447 Global Corporations
LAIS448 Global Environmental Issues
LAIS452 Corruption and Development
LAIS470 Technology and Gender Issues
LAIS485 Constitutional Law and Politics
LAIS486 Science and Technology Policy
LAIS487 Environmental Politics and Policy
LAIS488 Water Politics and Policy

Technology Specialization

Technology specialization students take 12 hours from the following list of EBG409 courses, of which 3 hours must be

Economics and Technology, and at least 3 hours must be a 400-level course that has EBG411 and/or EBG412 as pre-requisites.

EBGN314 Principles of Management
 EBG315 Business Strategy
 EBG320 Economics and Technology
 EBG409 Mathematical Economics[†]
 EBG455 Linear Programming[†]
 EBG495 Economic Forecasting
 EBG5XX^{††}

[†]Only counts if not taken as part of the EBG core.

^{††}Seniors with at least a 2.50 cumulative GPA may take a 500-level course with the consent of their department and the Dean of Graduate Studies.

Technology specialization students take 9 hours from the following list of LAIS courses. Courses used to satisfy the H&SS cluster requirements cannot be double counted.

LICM301 Professional Oral Communication
 LICM306 Selected Topics in Written Communication
 LAIS371 History of Technology
 LAIS470 Technology and Gender Issues
 LAIS476 Technology and International Development
 LAIS486 Science and Technology Policy

Global Business Specialization

Global Business specialization students take 12 hours from the following list of EBG courses, of which at least 3 hours must be a 400-level course that has EBG411 and/or EBG412 as prerequisites.

EBGN305 Financial Accounting
 EBG306 Managerial Accounting
 EBG314 Principles of Management
 EBG315 Business Strategy
 EBG342 Economic Development
 EBG345 Principles of Corporate Finance
 EBG409 Mathematical Economics[†]
 EBG455 Linear Programming[†]
 EBG441 International Trade
 EBG445 International Business Finance
 EBG495 Economic Forecasting
 EBG5XX^{††}

[†]Only counts if not taken as part of the EBG core.

^{††}Seniors with at least a 2.50 cumulative GPA may take a 500-level course with the consent of their department and the Dean of Graduate Studies.

Global Business specialization students take 6 hours from the following list of LAIS courses. Courses used to satisfy the H&SS cluster requirements cannot be double counted.

LICM301 Professional Oral Communication
 LICM306 Selected Topics in Written Communication
 LAIS285 Introduction to Law and Legal Systems
 LAIS335 International Political Economy of Latin America
 LAIS337 International Political Economy of Asia
 LAIS339 International Political Economy of the Middle East
 LAIS341 International Political Economy of Africa
 LAIS345 International Political Economy
 LAIS435 Latin American Development

LAIS436 Hemispheric Integration in the Americas
 LAIS437 Asian Development
 LAIS441 African Development
 LAIS442 Natural Resources and War in Africa
 LAIS447 Global Corporations
 LAIS448 Global Environmental Issues
 LAIS452 Corruption and Development

Minor Program

The minor in Economics requires that students complete 6 economics courses, for a total of 18 credit hours. Minors are required to take Principles of Microeconomics (EBGN311) and Principles of Macroeconomics (EBGN312). Students who complete the EBG311/312 sequence are not required to take EBG201 to satisfy their CSM core curriculum requirement. If a student has already taken EBG201 in addition to EBG311 and EBG312, he/she should choose 3 additional courses from the lists below. If a student has not taken EBG201, he/she should choose 4 additional courses from the lists below. Students can choose courses from either the economics focus or the business focus list (or both). Regardless of their course selection, the minor remains "Economics and Business." Economics courses taken as part of the Humanities and Social Sciences cluster electives can be counted toward the minor.

Area of Special Interest

The area of special interest in Economics and Business requires that students complete either Principles of Economics (EBGN201) and 3 other courses in economics and business chosen from the lists below, for a total of 12 credit hours, or Principles of Microeconomics (EBGN311), Principles of Macroeconomics (EBGN312) and 2 other courses chosen from the lists below, for a total of 12 credit hours. Students who complete the EBG311/312 sequence are not required to take EBG201 to satisfy their core curriculum requirement. Economics courses taken as part of the Humanities and Social Sciences cluster electives can be counted toward the area of special interest.

Economics Focus	lec.	lab.	sem.hrs.
EBGN310 Environmental and Resource Econ.	3		3
EBGN315 Business Strategy	3		3
EBGN320 Economics and Technology	3		3
EBGN330 Energy Economics	3		3
EBGN342 Economic Development	3		3
EBGN390 Econometrics	3		3
EBGN401 History of Economic Thought	3		3
EBGN409 Mathematical Economics	3		3
EBGN411 Intermediate Microeconomics	3		3
EBGN412 Intermediate Macroeconomics	3		3
EBGN441 International Economics	3		3
EBGN495 Economic Forecasting	3		3

Business Focus	lec.	lab.	sem.hrs.
EBGN304 Personal Finance	3		3
EBGN305 Financial Accounting	3		3
EBGN306 Managerial Accounting	3		3
EBGN314 Principles of Management	3		3
EBGN321 Engineering Economics	3		3

EBGN325 Operations Research	3	3
EBGN345 Corporate Finance	3	3
EBGN445 International Business Finance	3	3
EBGN455 Linear Programming	3	3

Description of Courses

Freshman Year

EBGN198. SPECIAL TOPICS IN ECONOMICS AND BUSINESS (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

EBGN199. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member. A student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Sophomore Year

EBGN201. PRINCIPLES OF ECONOMICS (I, II) The basic social and economic institutions of market capitalism. Contemporary economic issues. Business organization. Price theory and market structure. Economic analysis of public policies. Discussion of inflation, unemployment, monetary policy and fiscal policy. Students may elect to satisfy the economics core requirement by taking both EBG311 and EBG312 instead of this course. Students considering a major in economics are advised to take the EBG311/312 sequence instead of EBG201. 3 hours lecture; 3 semester hours.

EBGN298. SPECIAL TOPICS IN ECONOMICS AND BUSINESS (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

EBGN299. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member. A student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Junior Year

EBGN304. PERSONAL FINANCE (S) The management of household and personal finances. Overview of financial concepts with special emphasis on their application to issues faced by individuals and households: budget management, taxes, savings, housing and other major acquisitions, borrowing, insurance, investments, meeting retirement goals, and estate planning. Survey of principles and techniques for the management of a household's assets and liabilities. Study of financial institutions and their relationship to households, along with a discussion of financial instruments commonly held by individuals and families. 3 hours lecture; 3 semester hours.

EBGN305. FINANCIAL ACCOUNTING (I, II) Survey and evaluation of balance sheets and income and expense statements, origin and purpose. Evaluation of depreciation, depletion, and reserve methods for tax and internal management purposes. Cash flow analysis in relation to planning and decision making. Inventory methods and cost controls related to dynamics of production and processing. 3 hours lecture; 3 semester hours.

EBGN306. MANAGERIAL ACCOUNTING (II) Introduction to cost concepts and principles of management accounting including cost accounting. The course focuses on activities that create value for customers and owners of a company and demonstrates how to generate cost-accounting information to be used in management decision making. Prerequisite: EBG305. 3 hours lecture; 3 semester hours.

EBGN310. ENVIRONMENTAL AND RESOURCE ECONOMICS (I) (WI) Application of microeconomic theory to topics in environmental and resource economics. Topics include analysis of pollution control, benefit/cost analysis in decision-making and the associated problems of measuring benefits and costs, non-renewable resource extraction, measures of resource scarcity, renewable resource management, environmental justice, sustainability, and the analysis of environmental regulations and resource policies. Prerequisite: EBG201 or EBG311. 3 hours lecture; 3 semester hours.

EBGN311. MICROECONOMICS (I, II, S) How markets for goods and services work. Economic behavior of consumers, businesses, and government. Market structure and pricing. Efficiency and equity. Public policies. Students may satisfy the economics core requirement by taking the EBG311/312 sequence instead of EBG201. Students considering a major in economics are advised to skip EBG201 and begin with the EBG311/312 sequence. 3 hours lecture; 3 semester hours.

EBGN312. MACROECONOMICS (I, II, S) Analysis of gross domestic output and cyclical variability, plus the general level of prices and employment. The relationship between output and financial markets that affects the level of economic activity. Evaluation of government institutions and policy options for stabilization and growth. International trade and balance of payments. Students may satisfy the economics core requirement by taking the EBG311/312 sequence instead of EBG201. Students considering a major in economics are advised to skip EBG201 and begin with the EBG311/312 sequence. 3 hours lecture; 3 semester hours.

EBGN314. PRINCIPLES OF MANAGEMENT (II) Introduction of underlying principles, fundamentals, and knowledge required of the manager in a complex, modern organization. 3 hours lecture; 3 semester hours.

EBGN315. BUSINESS STRATEGY (II) An introduction to game theory and industrial organization (IO) principles at a practical and applied level. Topics include economies of scale and scope, the economics of the make-versus-buy decision, market structure and entry, dynamic pricing rivalry, strategic positioning, and the economics of organizational design. Prerequisite: EBG311. 3 hours lecture; 3 semester hours.

EBGN320. ECONOMICS AND TECHNOLOGY (II) The theoretical, empirical and policy aspects of the economics of technology and technological change. Topics include the economics of research and development, inventions and patenting, the Internet, e-commerce, and incentives for efficient implementation of technology. Prerequisite: EBG311. EBG312 is recommended but not required. 3 hours lecture; 3 semester hours.

EBGN321/CHEN421. ENGINEERING ECONOMICS (II) Time value of money concepts of present worth, future worth, annual worth, rate of return and break-even analysis applied to after-tax economic analysis of mineral, petroleum and general investments. Related topics on proper handling of (1) inflation and escalation, (2) leverage (borrowed money), (3) risk adjustment of analysis using expected value concepts, (4) mutually exclusive alternative analysis and service producing alternatives. 3 hours lecture; 3 semester hours.

EBGN325. OPERATIONS RESEARCH (I) This survey course introduces fundamental operations research techniques in the optimization areas of linear programming, network models (i.e., maximum flow, shortest path, and minimum cost flow), integer programming, and nonlinear programming. Stochastic (probabilistic) topics include queuing theory and simulation. Inventory models are discussed as time permits. The emphasis in this applications course is on problem formulation and obtaining solutions using Excel Software. Prerequisite: Junior Standing, MACS112. 3 hours lecture; 3 semester hours.

EBGN330. ENERGY ECONOMICS (I) Study of economic theories of optimal resource extraction, market power, market failure, regulation, deregulation, technological change and resource scarcity. Economic tools used to analyze OPEC, energy mergers, natural gas price controls and deregulation, electric utility restructuring, energy taxes, environmental impacts of energy use, government R&D programs, and other energy topics. Prerequisite: EBG201 or EBG311. 3 hours lecture; 3 semester hours.

EBGN342. ECONOMIC DEVELOPMENT (II) (WI) Theories of development and underdevelopment. Sectoral development policies and industrialization. The special problems and opportunities created by an extensive mineral endowment, including the Dutch disease and the resource-curse argument. The effect of value-added processing and export diversification on development. Prerequisite: EBG311. 3 lecture hours; 3 semester hours. Offered alternate years.

EBGN345. PRINCIPLES OF CORPORATE FINANCE (II) Introduction to corporate finance, financial management, and financial markets. Time value of money and discounted cash flow valuation, risk and returns, interest rates, bond and stock valuation, capital budgeting and financing decisions. Introduction to financial engineering and financial risk management, derivatives, and hedging with derivatives. Prerequisite: EBG305. 3 hours lecture; 3 semester hours.

EBGN390. ECONOMETRICS (I) (WI) Introduction to econometrics, including ordinary least-squares and single-equation models; two-stage least-squares and multiple-equation models; specification error, serial correlation, heteroskedasticity, and other problems; distributive-lag models and other extensions, hypothesis testing and forecasting applications. Prerequisites: EBG311 and MACS323. 3 hours lecture; 3 semester hours.

EBGN398. SPECIAL TOPICS IN ECONOMICS AND BUSINESS (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

EBGN399. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member. A student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Senior Year

EBGN401. HISTORY OF ECONOMIC THOUGHT (II) Study of the evolution of economic thinking since the 18th century. Topics include Adam Smith and the Classical School, Karl Marx and Socialism, Alfred Marshall and the Neoclassical School, John Maynard Keynes and the Keynesian School, and Milton Friedman and the New Classicism. Prerequisites: EBG311 and EBG312. 3 hours lecture; 3 semester hours.

EBGN402. FIELD SESSION (S) (WI) An applied course for students majoring in economics. The field session may consist of either participation in a computer simulation or an independent research project under the supervision of a faculty member. In the computer simulation, students work as part of the senior executive team of a company and are responsible for developing and executing a strategy for their company with on-going decisions on everything from new product development, to marketing, to finance and accounting. Prerequisites: EBG411 and EBG412; or permission of the instructor. 3 semester hours.

EBGN409. MATHEMATICAL ECONOMICS (II) Application of mathematical tools to economic problems. Coverage of mathematics needed to read published economic literature and to do graduate study in economics. Topics from differential and integral calculus, matrix algebra, differential equa-

tions, and dynamic programming. Applications are taken from mineral, energy, and environmental issues, requiring both analytical and computer solutions using programs such as GAMS and MATHEMATICA. Prerequisites: MACS213, EBG411, EBG412, MACS332 or MACS348; or permission of the instructor. 3 hours lecture; 3 semester hours.

EBGN411. INTERMEDIATE MICROECONOMICS (I, II) (WI) A second course in microeconomics. Compared to the earlier course, this course is more rigorous mathematically and quantitatively. It also places more emphasis on advanced topics such as game theory, risk and uncertainty, property rights, and external costs and benefits. Prerequisites: EBG311 and MACS213. 3 hours lecture; 3 semester hours.

EBGN412. INTERMEDIATE MACROECONOMICS (I, II) (WI) Intermediate macroeconomics provides a foundation for analyzing the long-run and short-run effects of fiscal and monetary policy on aggregate economic performance. Special emphasis on interactions between the foreign sector and the domestic economy. Analytical models are developed from Classical, Keynesian, and New Classical schools of thought. Prerequisites: EBG311, EBG312 and MACS213. 3 hours lecture; 3 semester hours.

EBGN441. INTERNATIONAL ECONOMICS (II) (WI) Theories and determinants of international trade, including static and dynamic comparative advantage and the gains from trade. The history of arguments for and against free trade. The political economy of trade policy in both developing and developed countries. Prerequisite: EBG411. 3 hours lecture; 3 semester hours. Offered alternate years.

EBGN445. INTERNATIONAL BUSINESS FINANCE (II) An introduction to financial issues of critical importance to multinational firms. Overview of international financial markets, the international monetary system, and foreign-exchange markets. International parity conditions, exchange-rate forecasting, swaps and swap markets. International investments, foreign-direct investment, corporate strategy, and the international debt crisis. Prerequisites: EBG305, EBG411, EBG412. 3 hours lecture; 3 semester hours.

EBGN455. LINEAR PROGRAMMING (I) This course addresses the formulation of linear programming models, examines linear programs in two dimensions, covers standard form and other basics essential to understanding the Simplex method, the Simplex method itself, duality theory, complementary slackness conditions, and sensitivity analysis. As time permits, multi-objective programming, an introduction to linear integer programming, and the interior point method are introduced. Applications of linear programming models discussed in this course include, but are not limited to, the areas of manufacturing, finance, energy, mining, transportation and logistics, and the military. Prerequisites: MACS332 or MACS348 or EBG409 or permission of instructor. 3 hours lecture; 3 semester hours.

EBGN495. ECONOMIC FORECASTING (II) An introduction to the methods employed in business and econometric forecasting. Topics include time series modeling, Box-Jenkins models, vector autoregression, cointegration, exponential smoothing and seasonal adjustments. Covers data collection methods, graphing, model building, model interpretation, and presentation of results. Topics include demand and sales forecasting, the use of anticipations data, leading indicators and scenario analysis, business cycle forecasting, GNP, stock market prices and commodity market prices. Includes discussion of links between economic forecasting and government policy. Prerequisites: EBG390, EBG411, EBG412. 3 hours lecture; 3 semester hours.

EBGN498. SPECIAL TOPICS IN ECONOMICS AND BUSINESS (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

EBGN499. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member. A student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Engineering

TERENCE E. PARKER, Professor and Division Director

WILLIAM A. HOFF, Associate Professor and Assistant Division Director

D. VAUGHAN GRIFFITHS, Professor

ROBERT J. KEE, George R. Brown Distinguished Professor

ROBERT H. KING, Professor

KEVIN MOORE, Gerard August Dobelman Chair and Professor

NING LU, Professor

MARK T. LUSK, Professor (and Physics)

NIGEL T. MIDDLETON, Professor, Executive Vice President for Academic Affairs, and Dean of Faculty

GRAHAM G. W. MUSTOE, Professor

PANKAJ K. (PK) SEN, Professor

JOEL M. BACH, Associate Professor

JOHN R. BERGER, Associate Professor

PANOS D. KIOUSIS, Associate Professor

MICHAEL MOONEY, Associate Professor

DAVID MUNOZ, Associate Professor

PAUL PAPAS, Associate Professor

MARCELO GODOY SIMOES, Associate Professor

JOHN P. H. STEELE, Associate Professor

CATHERINE K. SKOKAN, Associate Professor

TYRONE VINCENT, Associate Professor

RAY RUICHONG ZHANG, Associate Professor

CRISTIAN V. CIOBANU, Assistant Professor

KATHRYN JOHNSON, Clare Boothe Luce Assistant Professor

CARSTEN R. MEHRING, Assistant Professor

ANTHONY J. PETRELLA, Assistant Professor

NEAL SULLIVAN, Assistant Professor

MONEESH UPMANYU, Assistant Professor

MANOJA WEISS, Assistant Professor

RICHARD PASSAMANECK, Senior Lecturer

SANAA ABDEL-AZIM, Lecturer

RAVEL F. AMMERMAN, Lecturer

CARA COAD, Lecturer

JOSEPH P. CROCKER, Lecturer

TOM GROVER, Lecturer

CANDACE S. SULZBACH, Lecturer

ROBERT D. SUTTON, Lecturer

HAROLD W. OLSEN, Research Professor

JOAN P. GOSINK, Emerita Professor

MICHAEL B. McGRATH, Emeritus Professor

KARL R. NELSON, Emeritus Associate Professor

GABRIEL M. NEUNZERT, Emeritus Associate Professor

Note: Faculty for the environmental engineering specialty are listed in the Environmental Science and Engineering section of this Bulletin.

Program Description

The Division of Engineering offers a design-oriented, interdisciplinary, accredited non-traditional undergraduate program in engineering with specialization in civil, electrical, environmental or mechanical engineering. The program emphasizes fundamental engineering principles and requires in-depth understanding within one of the four specialty areas that are offered. Graduates are in a position to take advantage of a broad variety of professional opportunities, and are well-prepared for an engineering career in a world of rapid technological change.

The program leading to the degree Bachelor of Science in Engineering is accredited by the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Program Educational Objectives (*Bachelor of Science in Engineering*)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the Engineering Program at CSM has established the following program education objectives:

- ◆ Graduates will understand the design and analysis of engineering systems and the interdisciplinary nature of engineering.
- ◆ Graduates will incorporate an appreciation for issues involving earth, energy, materials and environment in their professional practice.
- ◆ Graduates will incorporate non-technical considerations (e.g., aesthetic, social, ethical, economic, etc.) in their professional practice.
- ◆ Graduates will contribute to the needs of society through engineering and professional practice, research, or service.

Curriculum

During their first two years at CSM, students complete a set of core courses that include basic sciences, in order to provide fundamental knowledge about nature and its phenomena, and engineering sciences, which build on the basic sciences and are focused on applications. Course work in mathematics is an essential part of the curriculum which gives engineering students essential tools for modeling, analyzing, and predicting physical phenomena. Physics and chemistry are required in order to provide an appropriate foundation in the physical sciences. The curriculum also includes liberal arts and international studies which enrich the educational experience and instill a greater understanding of how engineering decision impact human and social affairs.

Engineering design course work begins in the freshman year in Engineering Practice Introductory Course Sequence (EPICS) Design I, and continues through the four-year curriculum. This experience teaches design methodology and stresses the creative and synthesis aspects of the engineering profession. Systems-oriented courses are also included to provide experiences with the linkages that occur within the environment, human society, and engineered devices.

Students complete an advanced core that includes electric circuits, engineering mechanics, advanced mathematics, thermodynamics, economics, engineering design, and additional studies in liberal arts and international topics. In their last two years of study, students must choose a specialty in civil, electrical, environmental or mechanical engineering. Free electives (9 credits), at the student's discretion, can be used

to obtain an “area of special interest” of at least 12 semester hours or a minor of at least 18 semester hours in another department or division.

All students must complete a capstone design course, stressing the interdisciplinary nature of engineering systems. The projects are generated by customer demand, and include experiential verification to ensure a realistic design experience. Throughout their academic careers, students will benefit from interaction with well-qualified faculty who maintain research and professional leadership.

Prospective students should note that this is an integrated, broad-based and interdisciplinary engineering program. Analysis and design of engineering systems is emphasized with interdisciplinary application for industrial projects, structures and processes. For example, our unique Multidisciplinary Engineering Laboratory sequence promotes life-long learning skills using state-of-the-art instrumentation funded through grants from the Department of Education Fund for the Improvement of Post-Secondary Education, the National Science Foundation, the Parsons Foundation, Chevron, Kennecott Mining, and Fluor Daniel.

The **Civil Engineering Specialty** builds on the multidisciplinary engineering principles of the core curriculum to focus in Geotechnical and Structural Engineering. Civil Specialty students are also asked to choose three civil elective courses from a list that includes offerings from other civil-oriented departments at CSM such as Geological Engineering and Mining Engineering. These electives give students the opportunity for further specialization in, for example, Environmental Engineering or Applied Mechanics. Civil Specialty students interested in a more research-oriented component to their undergraduate curriculum are encouraged to take on an Independent Study project with one of the Civil Engineering Faculty. These projects can offer a useful insight into graduate school.

The **Electrical Engineering Specialty** builds on the engineering principals of the core curriculum to produce exposure to the fundamentals of electrical engineering. The program includes microprocessor-based systems design, electronic devices and systems, communications, signal processing, electromagnetic fields and waves, digital electronics and computer engineering, and control systems.

The **Environmental Engineering Specialty** introduces students to the fundamentals of environmental engineering including the scientific and regulatory basis of public health and environmental protection. Topics covered include environmental science and regulatory processes, water and wastewater engineering, solid and hazardous waste management, and contaminated site remediation.

The **Mechanical Engineering Specialty** complements the core curriculum with courses that provide depth in material mechanics and the thermal sciences with emphases in com-

putational methods and engineering design. Topics such as computational engineering, machine design, fluid mechanics, and heat transfer are an important part of the mechanical engineering program, which also includes control and vibration theory. The Mechanical Engineering program has close ties to the metallurgical and materials engineering, physics, chemical engineering and biological life sciences communities on campus, and undergraduates are encouraged to get involved in one of the large number of research programs conducted by the Mechanical Engineering faculty. Many students go on to graduate school.

Students in each of the four specialties will spend considerable time in laboratories. The division is well equipped with basic laboratory equipment, as well as PC-based instrumentation systems, and the program makes extensive use of computer-based analysis techniques.

The Division of Engineering is housed in George R. Brown Hall. Emphasis on hands-on education is reflected in the division’s extensive teaching and research laboratories. Interdisciplinary laboratories include the IBM Automated Systems Laboratory, the Multidisciplinary Engineering Laboratories, the USGS Soil Mechanics Laboratory, and environmental engineering laboratories in Coolbaugh Hall.

All students are encouraged to take the Fundamental of Engineering examination before graduation.

Degree Requirements in Engineering

Civil Specialty

Sophomore (Fall)	lec.	lab.	sem.hrs.
DCGN241 Statics	3		3
EBGN201 Principles of Economics	3		3
MACS213 Calc. for Scientists & Engineers III	4		4
PHGN200 Physics II	3	3	4.5
MACS260 Fortran 95 (or MACS 261)	2		2
PAGN2XX Physical Education		2	0.5
Total			17

Sophomore (Spring)	lec.	lab.	sem.hrs.
MACS315 Differential Equations	3		3
SYGN200 Human Systems	3		3
EGGN250 MEL I		4.5	1.5
EGGN320 Mechanics of Materials	3		3
EGGN351 Fluid Mechanics	3		3
EPIC251 Design II	3	1	3
PAGN2XX Physical Education		2	0.5
Total			17

Sophomore/Junior Field Session	lec.	lab.	sem.hrs.
EGGN234 Field Session			3

Junior (Fall)	lec.	lab.	sem.hrs.
EGGN342 Structural Theory	3		3
EGGN361 Soil Mechanics	3		3
EGGN363 Soil Mechanics Laboratory		3	1
EGGN315 Dynamics	3		3
EGGN413 Computer Aided Engineering	3		3
LAIS/EBGN Cluster Elective I	3		3
Total			16

Junior (Spring)	lec.	lab.	sem.hrs.	Junior Year Spring Semester	lec.	lab.	sem.hrs.
MACS348 Engineering Mathematics	3		3	LAIS/EBGN H&SS cluster elective I	3		3
EGGN464 Foundation Engineering	3		3	EGGN351 Fluid Mechanics	3		3
DCGN210 Introduction to Thermodynamics	3		3	EGGN385 Electronic Devices & Circuits	3	3	4
EGGN444/445 Design of Steel or Concrete Structures	3		3	EGGN386 Fundamentals of Engineering Electromagnetics	3		3
Civil Elective	3		3	EGGN389 Fund. of Electric Machinery	3	3	4
Free Elective	3		3	Total			17
Total			18	Junior-Senior Year Summer Field Session	lec.	lab.	sem.hrs.
Senior (Fall)	lec.	lab.	sem.hrs.	EGGN334 Field session - Electrical	3		3
MACS323 Probability and Statistics	3		3	Total			3
LAIS/EBGN Cluster Elective II	3		3	Senior Year Fall Semester	lec.	lab.	sem.hrs.
EGGN350 MEL II		4.5	1.5	LAIS/EBGN H&SS cluster elective II	3		3
EGGN491 Senior Design I	2	3	3	EGGN450 Multi-disc. Eng. Lab. III		3	1
DCGN381 Electrical Circuits , Electronics and Power	3		3	EGGN491 Senior Design I	2	3	3
Civil Elective	3		3	EGGN407 Feedback Control Systems	3		3
Total			16.5	Electrical Elective	6		6
Senior (Spring)	lec.	lab.	sem.hrs.	Total			16
LAIS/EBGN Cluster Elective III	3		3	Senior Year Spring Semester	lec.	lab.	sem.hrs.
EGGN492 Senior Design II	1	6	3	LAIS/EBGN H&SS cluster elective III	3		3
Civil Elective	3		3	EGGN492 Senior Design II	1	6	3
Free Elective	3		3	EGGN Electrical Specialty Elective	3		3
Free Elective	3		3	Free electives	9		9
Free Elective	3		3	Total			18
Total			18	Degree Total			141
Degree Total			138.50	Environmental Specialty			
Electrical Specialty				Sophomore Year Fall Semester	lec.	lab.	sem.hrs.
Sophomore Year Fall Semester	lec.	lab.	sem.hrs.	DCGN241 Statics	3		3
DCGN241 Statics	3		3	SYGN200	3		3
SYGN200 Human Systems	3		3	MACS213 Calc. for Scists & Engn'rs III	4		4
MACS213 Calc. for Scists & Engn'rs III	4		4	PHGN200 Physics II	3	3	4.5
PHGN200 Physics II	3	3	4.5	MACS260** Programming	2/3		2
MACS261 Computer Programming Concepts (C)	3		3	PAGN2XX Physical Education	2		0.5
PAGN2XX Physical Education	2		0.5	Total			17
Total			18	Sophomore Year Spring Semester	lec.	lab.	sem.hrs.
Sophomore Year Spring Semester	lec.	lab.	sem.hrs.	MACS315 Differential Equations	3		3
MACS315 Differential Equations	3		3	PAGN2XX Physical Education	2		0.5
PAGN2XX Physical Education	2		0.5	EGGN320 Mechanics of Materials	3		3
EBGN201 Principles of Economics	3		3	DCGN381 Elect. Circuits, Elect. & Pwr.	3		3
EGGN320 Mechanics of Materials	3		3	EGGN250 Multi-disc. Eng. Lab. I		4.5	1.5
DCGN381 Elect. Circuits, Elect. & Pwr.	3		3	EPIC251 Design II	3	1	3
EGGN250 Multi-disc. Eng. Lab. I		4.5	1.5	EBGN201 Principles of Economics	3		3
EPIC251 Design II	3	1	3	Total			17
Total			17	Junior Year Fall Semester	lec.	lab.	sem.hrs.
Junior Year Fall Semester	lec.	lab.	sem.hrs.	MACS323 Probability & Statistics	3		3
MACS323 Probability & Statistics	3		3	MACS348 Engineering Mathematics	3		3
MACS348 Engineering Mathematics	3		3	EGGN315 Dynamics	3		3
EGGN371 Engineering Thermodynamics	3		3	EGGN351 Fluid Mechanics	3		3
EGGN382 Engineering Circuit Analysis	3		3	EGGN353 Environmental Sci. & Eng. I	3		3
EGGN388 Information Systems Science	3		3	EGGN371 Engineering Thermodynamics	3		3
EGGN384 Digital Logic	3	3	4	Total			18
Total			19	Junior Year Spring Semester	lec.	lab.	sem.hrs.
				LAIS/EBGN H&SS cluster elective I	3		3
				EGGN350 Multi-disc. Eng. Lab. II		4.5	1.5
				EGGN354 Environmental Sci. & Eng. II	3		3
				EGGN Environmental Specialty Elective	3		3
				Free elective	6		6
				Total			16.5

	lec.	lab.	sem.hrs.
Junior-Senior Year Summer Field Session			
EGGN335 Field Session Environmental		3	
Total			3

	lec.	lab.	sem.hrs.
Senior Year Fall Semester			
EGGN491 Senior Design I	2	3	3
EGGN Environmental Specialty Elective	6		6
EGGN413 Computer Aided Engineering	3		3
Free elective	3		3
Total			15

	lec.	lab.	sem.hrs.
Senior Year Spring Semester			
LAIS/EBGN H&SS cluster elective II	3		3
LAIS/EBGN H&SS cluster elective III	3		3
EGGN492 Senior Design II	1	6	3
EGGN Environmental Specialty Elective	6		6
Free elective	3		3
Total			18

Degree Total 137.5

Mechanical Specialty

	lec.	lab.	sem.hrs.
Sophomore Year Fall Semester			
DCGN241 Statics	3		3
SYGN200 Human Systems	3		3
MACS213 Calc. for Scists & Engr's III	4		4
PHGN200 Physics II	3	3	4.5
MACS261** Programming	2/3		3
PAGN2XX Physical Education	2		0.5
Total			18

	lec.	lab.	sem.hrs.
Sophomore Year Spring Semester			
MACS315 Differential Equations	3		3
PAGN2XX Physical Education	2		0.5
SYGN202 Engineered Material Systems	3		3
EGGN320 Mechanics of Materials	3		3
DCGN381 Elect. Circuits, Elect. & Pwr.	3		3
EGGN250 Multi-disc. Eng. Lab. I		4.5	1.5
EPIC251 Design II	3	1	3
Total			17

	lec.	lab.	sem.hrs.
Summer Field Session			
EGGN235 Field Session - Mechanical			3
Total			3

	lec.	lab.	sem.hrs.
Junior Year Fall Semester			
MACS323 Probability & Statistics	3		3
MACS348 Engineering Mathematics	3		3
LAIS/EBGN H&SS cluster elective I	3		3
EGGN315 Dynamics	3		3
EGGN371 Engineering Thermodynamics	3		3
EGGN388 Information Systems Science	3		3
Total			18

	lec.	lab.	sem.hrs.
Junior Year Spring Semester			
EBGN201 Principles of Economics	3		3
EGGN351 Fluid Mechanics	3		3
EGGN350 Multi-disc. Eng. Lab. II		4.5	1.5
EGGN407 Feedback Control Systems	3		3
EGGN413 Computer-Aided Engineering	3		3
EGGN Mechanical Specialty Elective	3		3
Total			16.5

	lec.	lab.	sem.hrs.
Senior Year Fall Semester			
EGGN450 Multi-disc. Eng. Lab. III	3		1
EGGN491 Senior Design I	2	3	3
LAIS/EBGN H&SS cluster elective II	3		3
EGGN471 Heat Transfer	3		3
EGGN411 Machine Design	3	3	4
Free elective	3		3
Total			17

	lec.	lab.	sem.hrs.
Senior Year Spring Semester			
LAIS/EBGN H&SS cluster elective III	3		3
EGGN492 Senior Design II	1	6	3
Mechanical Electives	6		6
Free elective	6		6
Total			18

Degree Total 140.5

**Environmental and Mechanical Engineering students may take the 2-credit MACS260 Fortran or Java Programming or the 3-credit MACS261 Programming Concepts in C.

Engineering Specialty Electives
Civil Specialty

Civil Specialty students are required to take three civil elective courses from the following list. The electives have been grouped by themes for convenience only. When choosing their three courses, students can elect for breadth across themes or depth within a theme.

Students must take at least two courses marked (A).

Environmental

EGGN353 (A)Fundamentals of Environmental Science and Engineering I
EGGN354 (A)Fundamentals of Environmental Science and Engineering II
EGGN451 (A)Hydraulic Problems
EGGN453 (A)Wastewater Engineering
EGGN454 (A)Water Supply Engineering
EGGN455 (A)Solid and Hazardous Waste Engineering
EGGN456 (A)Scientific Basis of Environmental Regulations
EGGN457 (A)Site Remediation Engineering

General

EGGN333 (A)Surveying II
EGGN407 (A)Feedback control systems
EGGN460 (A)Numerical Methods for Engineers
EBGN421 (A)Engineering Economics
EBGN553 (B)Project Management
EGGN399/499 (B)Independent Study (Civil)

Geotechnical

EGGN465 (A)Unsaturated Soil Mechanics
EGGN448 (A)Advanced Soil Mechanics
EGES534 (A)Soil Behavior
EGES598 (A)Soil dynamics and foundation vibrations
MNGN321 (A)Introduction to Rock Mechanics
MNGN404 (B)Tunneling
MNGN405 (B)Rock Mechanics in Mining
MNGN406 (B)Design and Support of Underground Excavations
GEGN466 (B)Groundwater Engineering
GEGN468 (B)Engineering Geology and Geotechnics
GEGN473 (B)Site investigation

Mechanics

- EGGN422 (A)Advanced Mechanics of Materials
- EGGN442 (A)Finite Element Methods For Engineers
- EGGN473 (A)Fluid Mechanics II
- EGGN478 (A)Engineering Dynamics

Structural

- EGGN441 (A)Advanced Structural Analysis
- EGGN444/445 (A)Steel Design or Concrete Design

Graduate courses in EG and elsewhere may occasionally be approved as civil electives on an ad hoc basis. In order for a course that is not listed here to be considered, the student should submit a written request in advance to their faculty advisor enclosing a copy of the course syllabus.

Electrical Specialty

Electrical specialty students are required to take three courses from the following list of electrical technical electives:*

- EGGN430 Biomedical Instrumentation
- EGGN482 Microcomputer Architecture and Interfacing
- EGGN483 Analog and Digital Communications Systems
- EGGN484 Power Systems Analysis
- PHGN300 Modern Physics
- EGGN485 Introduction to High Power Electronics
- PHGN440 Solid State Physics
- PHGN435 Interdisciplinary Microelectronics Processing Laboratory

*Additional courses are approved special topics with a number EGGN398/498 and all graduate courses taught in the Electrical Engineering specialty area. Students should consult their faculty advisor for guidance.

Environmental Specialty

All students pursuing the Environmental Specialty are required to take EGGN/ESGN353 and EGGN/ESGN354. These courses are prerequisites for many 400 level Environmental Specialty courses. In addition students are required to take five courses from the following list:

- ESGN401 Fundamentals of Ecology
- ESGN440 Environmental Pollution: Sources, Characteristics, Transport and Fate
- EGGN451 Hydraulic Problems
- EGGN/ESGN453 Wastewater Engineering
- EGGN/ESGN454 Water Supply Engineering
- EGGN/ESGN456 Scientific Basis of Environmental Regulations
- EGGN/ESGN457 Site Remediation Engineering
- ESGN462 Solid Waste Minimization and Recycling
- ESGN463 Pollution Prevention Fundamentals and Practice
- GEGN466 Groundwater Engineering

Students should consult their faculty advisor for guidance on course substitutions

Mechanical Specialty

The list of approved Mechanical Engineering electives appears below. Students are required to take three of these courses and at least one must be from List A. In addition to these courses, any graduate course taught by a member of the Mechanical Engineering faculty will also be counted as a

Mechanical Elective. Students are welcome to petition to have a course approved, and the petition form is provided on the Mechanical Engineering web site. Courses are occasionally added to this list with the most updated version maintained on the Mechanical Engineering web site.

List A

- EGGN422 Advanced Mechanics of Materials
- EGGN473 Fluid Mechanics II
- EGGN403 Thermodynamics II
- EGGN478 Engineering Dynamics

List B

- EGGN389 Fundamentals of Electric Machinery
- EGGN400 Introduction to Robotics
- EGGN420 Biomedical Engineering
- EGGN425 Musculoskeletal Biomechanics
- EGGN430 Biomedical Instrumentation
- EGGN442 Finite Element Methods for Engineering
- EGGN444 Design of Steel Structures
- EGGN460 Numerical Methods for Engineers
- EBGN321 Engineering Economics
- ESGN527 Watersheds System Analysis
- MTGN/EGGN390 Materials and Manufacturing Processes
- MTGN445 Mechanical Properties of Materials
- MTGN450 Statistical Control of Materials Processes
- MTGN464 Forging and Forming
- MTGN477/475 Welding Metallurgy
- MLGN/MTGN570 Introduction to Biocompatibility of Materials
- PEGN361 Completion Engineering (II)
- PEGN311 Drilling Engineering Principles
- PEGN515 Drilling Engineering Principles
- PHGN350 Intermediate Mechanics
- PEGN435 Microelectronics Processing Laboratory
- PHGN440 Solid State Physics

Division of Engineering Areas of Special Interest and Minor Programs

General Requirements

A **Minor Program** of study must consist of a minimum of 18 credit hours of a logical sequence of courses, only three hours of which may be taken at the 100- or 200- level. No more than six credit hours of the sequence may be taken in the student's degree granting department.

An **Area of Special Interest (ASI)** must consist of a minimum of 12 credit hours of a logical sequence of courses, only three hours of which may be taken at the 100- or 200-level. No more than three credit hours of the sequence may be specifically required by the degree program in which the student is graduating.

A **Minor Program / Area of Special Interest** declaration (available in the Registrar's Office) should be submitted for approval prior to the student's completion of half of the hours proposed to constitute the program. Approvals are required from the Director of the Engineering Division, the student's advisor, and the Department Head or Division Director in the department or division in which the student is enrolled.

The **Humanitarian Engineering Minor** (HE) is an alternative available to engineering students seeking to have a direct impact on meeting the basic needs of humanity. This minor program lies at the intersection of society, culture, and technology. Technologically-oriented humanitarian projects are intended to provide fundamental needs (food, water, waste treatment, shelter, and power) when these are missing or inadequate for human development, or higher-level needs for underserved communities within developed and developing countries. The Humanitarian Engineering Minor combines courses in LAIS with technical courses offered through the Engineering Division or other appropriate applied courses offered on the Mines campus (or at other universities, subject to Humanitarian Engineering Steering Committee approval). Students may also wish to investigate the 18-credit Minor in Humanitarian Studies and Technology.

Programs in the Engineering Division

The Engineering Division offers minor and ASI programs to meet two sets of audiences. The first is a program in General Engineering which is suited to students who are not pursuing an engineering degree. This program offers foundation coursework in engineering which is compatible with many of the topics in the Fundamentals of Engineering examination. The second is a program in Engineering Specialties which is suited to students pursuing an engineering degree, and who have therefore completed much of the coursework represented in the General Engineering program. Students may opt to pursue minors or ASIs in civil, electrical, environmental or mechanical engineering within the Engineering Specialties program.

Students wishing to enroll in either program must satisfy all prerequisite requirements for each course in a chosen sequence. Students in the sciences or mathematics will therefore be better positioned to prerequisite requirements in the General Engineering program, while students in engineering disciplines will be better positioned to meet the prerequisite requirements for courses in the Engineering Specialties.

The courses listed below, constituting each program and the specialty variations, are offered as guidelines for selecting a logical sequence. In cases where students have unique backgrounds or interests, these sequences may be adapted accordingly through consultation with faculty in the Engineering Division.

General Engineering Program

A twelve (ASI) or eighteen hour (minor) sequence must be selected from:

DCGN241 Statics	3 sem hrs.
EGGN320 Mechanics of Materials	3 sem hrs.
EGGN351 Fluid Mechanics	3 sem hrs.
EGGN371 Thermodynamics	3 sem hrs.
DCGN381 Electrical Circuits, Electronics and Power	3 sem hrs.
EGGN315 Dynamics	3 sem hrs.
EBGN421 Engineering Economics	3 sem hrs.

Note: Multidisciplinary Engineering Laboratories I, II and III (EGGN 250, 350 and 450, respectively) may be taken as laboratory supplements to DCGN 381, EGGN351 and EGGN320.

Engineering Specialties Program

Civil

A twelve (ASI) or eighteen hour (minor) sequence must be selected from:

EGGN342 Structural Theory	3 sem hrs.
EGGN361 Soil Mechanics	3 sem hrs.
EGGN363 Soil Mechanics Laboratory	1 sem hrs.
EGGN441 Advanced Structural Theory	3 sem hrs.
EGGN444 Design of Steel Structures	3 sem hrs.
EGGN445 Design of Reinforced Concrete Structures	3 sem hrs.
EGGN448 Advanced Soil Mechanics	3 sem hrs.
EGGN451 Hydraulic Problems	3 sem hrs.
EGGN464 Foundations	3 sem hrs.
EGGN333 Surveying II	3 sem hrs.
EGGN354 Fundamentals of Environmental Science and Engineering II	3 sem hrs.
EGGN422 Advanced Mechanics of Materials	3 sem hrs.
EGGN442 Finite Element Methods for Engineers	3 sem hrs.
EGGN453 Wastewater Engineering	3 sem hrs.
EGGN454 Water Supply Engineering	3 sem hrs.
EGGN465 Unsaturated Soil Mechanics	3 sem hrs.
EGGN478 Engineering Dynamics	3 sem hrs.
EGGN498 Numerical Methods for Engineers	3 sem hrs.
EGGN498 Advanced Soil Mechanics	3 sem hrs.
EGGN499 Dynamics of Structures and Soils	3 sem hrs.
MNGN321 Introduction to Rock Mechanics	3 sem hrs.
EGGN467 Groundwater Engineering	4 sem hrs.
EGGN468 Engineering Geology and Geotechnics	4 sem hrs.

Electrical

A twelve (ASI) or eighteen hour (minor) sequence must be selected from a basic electrical program comprising:*

DCGN381 Introduction to Electrical Circuits, Electronics and Power	3 sem hrs.
EGGN382 Engineering Circuit Analysis	3 sem hrs.

Additional courses are to be selected from:

EGGN334 Engineering Field Session, Electrical Specialty	3 sem hrs.
EGGN384 Digital Logic	4 sem hrs.
EGGN385 Electronic Devices and Circuits	4 sem hrs.
EGGN386 Fundamentals of Engineering Electromagnetics	3 sem hrs.
EGGN388 Information Systems Science	3 sem hrs.
EGGN389 Fundamentals of Electric Machinery	4 sem hrs.
EGGN407 Introduction to Feedback Control Systems	3 sem hrs.
EGGN430 Biomedical Instrumentation	
EGGN482 Microcomputer Architecture and Interfacing	4 sem hrs.
EGGN483 Analog & Digital Communication Systems	4 sem hrs.
EGGN484 Power Systems Analysis	3 sem hrs.
EGGN485 Introduction to High Power Electronics	3 sem hrs.

*Additional courses are approved special topics with a number EGGN398/498 and all graduate courses taught in the Electrical Engineering specialty area. Students should consult their faculty advisor for guidance

Environmental Science and Engineering Minor and ASI – see Environmental Science and Engineering

Mechanical

A twelve (ASI) or eighteen hour (minor) sequence must be selected from:

EGGN351 Fluid Mechanics	3 sem hrs.
EGGN403 Thermodynamics II	3 sem hrs.
EGGN471 Heat Transfer	3 sem hrs.
EGGN473 Fluid Mechanics II	3 sem hrs.
EGGN411 Machine Design	3 sem hrs.
EGGN413 Computer-Aided Engineering	3 sem hrs.
EGGN400 Introduction to Robotics	3 sem hrs.
EGGN407 Feedback Control Systems	3 sem hrs.
EGGN422 Advanced Mechanics of Materials	3 sem hrs.

Combined Engineering Baccalaureate and Engineering Systems Masters Degrees

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

Students must apply to enter this program by the beginning of their Senior year and must have a minimum GPA of 3.0. To complete the undergraduate portion of the program, students must successfully finish the classes indicated in any of the four specialty programs (civil, electrical, environmental or mechanical engineering). At the beginning of the Senior year, a *pro forma* graduate school application is submitted and as long as the undergraduate portion of the program is successfully completed, the student is admitted to the Engineering Systems graduate program.

Students are required to take thirty-six credit hours for the M.S. degree. However, six credit hours can be applied to both the B.S. and M.S. degrees, as long as they are approved technical elective courses at the 4XX level or higher. Up to nine credit hours of 4XX level courses may be used toward the M.S. degree. The remainder of the courses will be at the graduate level (5XX and above). Students will need to choose a program specialty (Civil, Electrical, Mechanical, and Systems). The Engineering Division Graduate Bulletin provides details for each of these programs and includes specific instructions regarding required and elective courses for each. Students may switch from the combined program which includes a non-thesis Master of Science degree to a M.S. degree with a thesis option; however, if students change degree programs they must satisfy all degree requirements for the M.S. with thesis degree.

Interested students can obtain additional information from the Division of Engineering.

Combined Engineering Physics or Chemistry Baccalaureate and Engineering Systems Masters Degrees

The Division of Engineering in collaboration with the Departments of Physics and Chemistry offers five-year programs in which students have the opportunity to obtain specific engineering skills to complement their physics or chemistry background. Physics or chemistry students in this program fill in their technical and free electives over their standard four year Engineering Physics or Chemistry B.S. program with a reduced set of engineering classes. These classes come in one of two specialties within the division: Electrical engineering and Mechanical engineering. At the end of the fourth year, the student is awarded an Engineering Physics B.S. or Chemistry B.S., as appropriate. Students in this program are automatically entered into the Engineering Systems Masters degree program. Just as any graduate student, it is possible for them to graduate in one year (non-thesis option) with a Masters of Science in Engineering Systems degree.

Students must apply to enter this program by the beginning of their Senior year and must have a minimum GPA of 3.0. To complete the undergraduate portion of the program, students must successfully finish the classes indicated by the “typical” class sequence for the appropriate track. At the beginning of the Senior year, a *pro forma* graduate school application is submitted and as long as the undergraduate portion of the program is successfully completed, the student is admitted to the Engineering Systems graduate program.

Interested students can obtain additional information and detailed curricula from the Division of Engineering or the Physics Department.

Description of Courses

Freshman Year

EGGN198. SPECIAL TOPICS IN ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

EGGN199. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: “Independent Study” form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Sophomore Year

EGGN234. ENGINEERING FIELD SESSION, CIVIL SPECIALTY (S) The theory and practice of modern surveying. Lectures and hands-on field work teaches horizontal, vertical, and angular measurements and computations using traditional and modern equipment. Subdivision of land and applications to civil engineering practice, GPS and astronomic

observations. Prerequisite: None. Three weeks (6 day weeks) in summer field session; 3 semester hours.

EGGN235. ENGINEERING FIELD SESSION, MECHANICAL SPECIALTY (S) This course provides the student with hands-on experience in the use of modern engineering tools as part of the design process including modeling, fabrication, and testing of components and systems. Student use engineering, mathematics and computers to conceptualize, model, create, test, and evaluate components and systems of their creation. Teamwork is emphasized by having students work in teams. Prerequisites: PHGN200/201, MACS260/261 and EPIC251. Three weeks in summer field session; 3 semester hours.

EGGN250. MULTIDISCIPLINARY ENGINEERING LABORATORY I (I, II) (WI) Laboratory experiments integrating instrumentation, circuits and power with computer data acquisitions and sensors. Sensor data is used to transition between science and engineering science. Engineering Science issues like stress, strains, thermal conductivity, pressure and flow are investigated using fundamentals of equilibrium, continuity, and conservation. Prerequisite: DCGN381 or concurrent enrollment. 4.5 hours lab; 1.5 semester hour.

EGGN298. SPECIAL TOPICS IN ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

Junior Year

EGGN315. DYNAMICS (I, II, S) Absolute and relative motions. Kinetics, work-energy, impulse-momentum, vibrations. Prerequisite: DCGN241 and MACS315. 3 hours lecture; 3 semester hours.

EGGN320. MECHANICS OF MATERIALS (I, II) Fundamentals of stresses and strains, material properties. Axial, torsion, bending, transverse and combined loadings. Stress at a point; stress transformations and Mohr's circle for stress. Beams and beam deflections, thin-wall pressure vessels, columns and buckling, fatigue principles, impact loading. Prerequisite: DCGN241 or MNGN317. 3 hours lecture; 3 semester hours.

EGGN333. SURVEYING II (I) Engineering projects with local control using levels, theodolites and total stations, including surveying applications of civil engineering work in the "field". Also includes engineering astronomy and computer generated designs; basic road design including centerline staking, horizontal and vertical curves, slope staking and earthwork volume calculations. Use of commercial software for final plan/profile and earthwork involved for the road project data collected in the field. Conceptual and mathematical knowledge of applying GPS data to engineering projects. Some discussion of the principles and equations of projections (Mercator, Lambert, UTM, State Plane, etc.) and their relationship to the databases of coordinates based on (North

American Datum) NAD '27, NAD '83 and (High Accuracy Reference Network) HARN. Pre-requisite: EGGN234. 2 hours lecture; 8-9 field work days; 3 semester hours.

EGGN334. ENGINEERING FIELD SESSION, ELECTRICAL SPECIALTY (S) Experience in the engineering design process involving analysis, design, and simulation. Students use engineering, mathematics and computers to model, analyze, design and evaluate system performance. Teamwork emphasized. Prerequisites: EGGN382, EGGN388, and two of the following: EGGN384, EGGN385, and EGGN389. Three weeks in summer field session; 3 semester hours.

EGGN335. ENGINEERING FIELD SESSION, ENVIRONMENTAL SPECIALTY (S) The environmental module is intended to introduce students to laboratory and field analytical skills used in the analysis of an environmental engineering problem. Students will receive instruction on the measurement of water quality parameters (chemical, physical, and biological) in the laboratory and field. The student will use these skills to collect field data and analyze a given environmental engineering problem. Prerequisites: EGGN353, EPIC251, MACS323. Three weeks in summer field session; 3 semester hours.

EGGN340. COOPERATIVE EDUCATION (I,II,S) Supervised, full-time engineering-related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Engineering Division Faculty Co-op Advisor prior to enrolling to clarify the educational objectives for their individual Co-op program. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 3 semester hours credit will be granted once toward degree requirements. Credit earned in EGGN340, Cooperative Education, may be used as free elective credit hours or a civil specialty elective if, in the judgment of the Co-op Advisor, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives or civil electives requires the student to submit a "Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements" form obtained from the Career Center to the Engineering Division Faculty Co-op Advisor.

EGGN342. STRUCTURAL THEORY (I, II) Analysis of determinate and indeterminate structures for both forces and deflections. Influence lines, work and energy methods, moment distribution, matrix operations, computer methods. Prerequisite: EGGN320. 3 hours lecture; 3 semester hours.

EGGN350. MULTIDISCIPLINARY ENGINEERING LABORATORY II (I, II) (WI) Laboratory experiments integrating electrical circuits, fluid mechanics, stress analysis, and other engineering fundamentals using computer data acquisition and transducers. Fluid mechanics issues like compressible and incompressible fluid flow (mass and volumetric), pres-

sure losses, pump characteristics, pipe networks, turbulent and laminar flow, cavitation, drag, and others are covered. Experimental stress analysis issues like compression and tensile testing, strain gage installation, Young's Modulus, stress vs. strain diagrams, and others are covered. Experimental stress analysis and fluid mechanics are integrated in experiments which merge fluid power of the testing machine with applied stress and displacement of material specimen. Prerequisite: EGGN250. Prerequisite or concurrent enrollment: EGGN351, EGGN320. 4.5 hours lab; 1.5 semester hour.

EGGN351. FLUID MECHANICS (I, II, S) Properties of liquids, manometers, one-dimensional continuity. Bernoulli's equation, the impulse momentum principle, laminar and turbulent flow in pipes, meters, pumps, and turbines. Prerequisite: DCGN241 or MNGN317. 3 hours lecture; 3 semester hours.

EGGN/ESGN353. FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I (I, II) Topics covered include: history of water related environmental law and regulation, major sources and concerns of water pollution, water quality parameters and their measurement, material and energy balances, water chemistry concepts, microbial concepts, aquatic toxicology and risk assessment. Prerequisite: Junior standing or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN/ESGN354. FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING II (II) Introductory level fundamentals in atmospheric systems, air pollution control, solid waste management, hazardous waste management, waste minimization, pollution prevention, role and responsibilities of public institutions and private organizations in environmental management (relative to air, solid and hazardous waste). Prerequisite: Junior standing or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN361. SOIL MECHANICS (I, II) An introductory course covering the engineering properties of soil, soil phase relationships and classification. Principle of effective stress. Seepage through soils and flow nets. One-dimensional consolidation theory. Soil compressibility and settlement prediction. Shear strength of soils. Pore pressure parameters. Introduction to earth pressure and slope stability calculations. Prerequisite: EGGN320. 3 hours lecture; 3 semester hours.

EGGN363. SOIL MECHANICS LABORATORY (I, II) Introduction to laboratory testing methods in soil mechanics. Classification, permeability, compressibility, shear strength. Prerequisite: EGGN361 or concurrent enrollment. 3 hours lab; 1 semester hour.

EGGN371. THERMODYNAMICS I (I, II, S) Definitions, properties, temperature, phase diagrams, equations of state, steam tables, gas tables, work, heat, first and second laws of thermodynamics, entropy, ideal gas, phase changes, availability, reciprocating engines, air standard cycles, vapor cycles. Prerequisite: MACS213/223. 3 hours lecture; 3 semester hours.

EGGN382. ENGINEERING CIRCUIT ANALYSIS (I, II) This course provides the theoretical fundamentals to understand and analyze complex electric circuits with the required mathematical tools. The key covered topics are: (i) Applications of linearity, superposition, Thévenin and Norton equivalent circuits, mesh and nodal analysis for complex electrical networks, (ii) Sinusoidal steady state analysis, (iii) Application of computer aided analysis for electrical networks, (iv) AC power circuit analysis, (v) Fourier series for analysis of ac circuits, (vi) Laplace transform for transient analysis of electric circuits, (vii) Frequency response, poles, zeros, transfer function, Bode plots and filter design, (viii) Ideal and non-ideal operational amplifiers and (ix) ideal transformer. Prerequisites: DCGN 381 or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN384. DIGITAL LOGIC (I, II) Fundamentals of digital logic design. Covers combinational and sequential logic circuits, programmable logic devices, hardware description languages, and computer-aided design (CAD) tools. Laboratory component introduces simulation and synthesis software and hands-on hardware design. Prerequisites: DCGN381 or equivalent. 3 hours lecture; 3 hours lab; 4 semester hours.

EGGN385. ELECTRONIC DEVICES AND CIRCUITS (I, II) Semiconductor materials and characteristics, junction diode operation, bipolar junction transistors, field effect transistors, biasing techniques, four layer devices, amplifier and power supply design, laboratory study of semiconductor circuit characteristics. Prerequisite: EGGN 382. 3 hours lecture; 3 hours lab; 4 semester hours.

EGGN 386. FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS (I, II) This course provides an introduction to electromagnetic theory as applied to electrical engineering problems in wireless communications, transmission lines, and high-frequency circuit design. The theory and applications are based on Maxwell's equations, which describe the electric and magnetic force-fields, the interplay between them, and how they transport energy. Matlab and PSPICE will be used in homework assignments, to perform simulations of electromagnetic interference, electromagnetic energy propagation along transmission lines on printed circuit boards, and antenna radiation patterns. Prerequisites: EGGN 382, MACS 348 and/or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN388. INFORMATION SYSTEMS SCIENCE (I, II) The interpretation, representation and analysis of time-varying phenomena as signals which convey information and noise; a quantitative treatment on the properties of information and noise, and the degradation of signal fidelity through distortion, band limitation, interference and additive noise. Fourier, Laplace, and Z transforms. Introductory applications in the analysis of dynamic data streams emanating from mechanical, structural and electronic systems, system

diagnostics, data acquisition, control and communications. Prerequisite: DCGN381 and MACS315. Corequisite: MACS348. 3 hours lecture; 3 semester hours.

EGGN389. FUNDAMENTALS OF ELECTRIC MACHINERY I (I, II) 3-phase electrical circuits, magnetic circuit concepts and materials, transformer analysis and operation, steady state and dynamic analysis of rotating machines, synchronous and polyphase induction motors, fractional horsepower machines, laboratory study of external characteristics of machines and transformers. Prerequisite: EGGN382. 3 hours lecture; 3 hours lab; 4 semester hours.

EGGN390/MTGN390. MATERIALS AND MANUFACTURING PROCESSES (II) This course focuses on available engineering materials and the manufacturing processes used in their conversion into a product or structure as critical considerations in design. Properties, characteristics, typical selection criteria, and applications are reviewed for ferrous and nonferrous metals, plastics and composites. The nature, features, and economics of basic shaping operations are addressed with regard to their limitations and applications and the types of processing equipment available. Related technology such as measurement and inspection procedures, numerical control systems and automated operations are introduced throughout the course. Prerequisite: EGGN320, SYGN202. 3 hours lecture; 3 semester hours.

EGGN398. SPECIAL TOPICS IN ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

EGGN399. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Senior Year

EGGN400/MNGN400. INTRODUCTION TO ROBOTICS (II) Overview and introduction to the science and engineering of intelligent mobile robotics and robotic manipulators. Covers guidance and force sensing, perception of the environment around a mobile vehicle, reasoning about the environment to identify obstacles and guidance path features and adaptively controlling and monitoring the vehicle health. A lesser emphasis is placed on robot manipulator kinematics, dynamics, and force and tactile sensing. Surveys manipulator and intelligent mobile robotics research and development. Introduces principles and concepts of guidance, position, and force sensing; vision data processing; basic path and trajectory planning algorithms; and force and position control. Prerequisite: MACS261 and DCGN381. 2 hours lecture; 1 hour lab; 3 semester hours.

EGGN403. THERMODYNAMICS II (II) This course includes the study of thermodynamic relations, Clapeyron equation, mixtures and solutions, Gibbs function, combustion processes, first and second law applied to reacting systems, third law of thermodynamics, real combustion processes, equilibrium of multicomponent systems, simultaneous chemical reactions of real combustion processes, ionization, overview of the major characteristics of spark-ignition and compression-ignition engines, define parameters used to describe engine operation, develop the necessary thermodynamic and combustion theory required for a quantitative analysis of engine behavior, develop an integrated treatment of the various methods of analyzing idealized models of internal combustion engine cycles, and finally summarize how operating characteristics of spark-ignition and compression-ignition engine depend on the major engine design and operating variables. Prerequisite: EGGN371, EGGN471. 3 hours lecture; 3 semester hours.

EGGN407. INTRODUCTION TO FEEDBACK CONTROL SYSTEMS (I, II) System modeling through an energy flow approach is presented, with examples from linear electrical, mechanical, fluid and/or thermal systems. Analysis of system response in both the time domain and frequency domain is discussed in detail. Feedback control design techniques, including PID, are analyzed using both analytical and computational methods. Prerequisites: DCGN381 and MACS315. 3 hours lecture; 3 semester hours.

EGGN411. MACHINE DESIGN (I, II) Introduction to the principles of mechanical design. Consideration of the behavior of materials under static and cyclic loading; failure considerations. Application of the basic theories of mechanics, kinematics, and mechanics of materials to the design of basic machine elements, such as shafts, keys, and coupling; journal bearings, antifriction bearings, wire rope, gearing; brakes and clutches, welded connections and other fastenings. Prerequisite: EPIC251, EGGN315, and EGGN320. 3 hours lecture; 3 hours lab; 4 semester hours.

EGGN413. COMPUTER AIDED ENGINEERING (I, II) This course introduces the student to the concept of computer-aided engineering. The major objective is to provide the student with the necessary background to use the computer as a tool for engineering analysis and design. The Finite Element Analysis (FEA) method and associated computational engineering software have become significant tools in engineering analysis and design. This course is directed to learning the concepts of FEA and its application to civil and mechanical engineering analysis and design. Note that critical evaluation of the results of a FEA using classical methods (from statics and mechanics of materials) and engineering judgment is employed throughout the course. Prerequisite: EGGN320. 3 hours lecture; 3 semester hours.

EGGN422. ADVANCED MECHANICS OF MATERIALS (II) General theories of stress and strain; stress and strain transformations, principal stresses and strains, octahedral shear stresses, Hooke's law for isotropic material, and failure criteria. Introduction to elasticity and to energy methods. Torsion of noncircular and thin-walled members. Unsymmetrical bending and shear-center, curved beams, and beams on elastic foundations. Introduction to plate theory. Thick-walled cylinders and contact stresses. Prerequisite: EGGN320, EGGN413. 3 hours lecture; 3 semester hours.

EGGN420 (BELS420). INTRODUCTION TO BIOMEDICAL ENGINEERING (I) The application of engineering principles and techniques to the human body presents many unique challenges. The discipline of Biomedical Engineering has evolved over the past 50 years to address these challenges. Biomedical Engineering is a diverse, seemingly all-encompassing field that includes such areas as biomechanics, biomaterials, bioinstrumentation, medical imaging, rehabilitation. This course is intended to provide an introduction to, and overview of, Biomedical Engineering. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply various engineering principles to the human body. Prerequisites: DCGN421, DCGN381, EGGN320, EGGN351 or instructor permission. 3 hours lecture; 3 semester hours.

EGGN425(BELS425). MUSCULOSKELETAL BIOMECHANICS (II) This course is intended to provide engineering students with an introduction to musculoskeletal biomechanics. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply engineering principles to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. Prerequisite: DCGN421, EGGN320, EGGN420/BELS420, or instructor permission. 3 hours lecture; 3 semester hours.

EGGN430(BELS430): BIOMEDICAL INSTRUMENTATION The acquisition, processing, and interpretation of biological signals present many unique challenges to the Biomedical Engineer. This course is intended to provide students with an introduction to, and appreciation for, many of 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. Prerequisite: EGGN250 MEL I, DCGN381, EGGN420/BELS420, or instructor permission. 3 hours lecture; 3 semester hours.

EGGN441. ADVANCED STRUCTURAL ANALYSIS (II) Introduction to advanced structural analysis concepts. Non-prismatic 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: EGGN342. 3 hour lectures; 3 semester hours.

EGGN442. FINITE ELEMENT METHODS FOR ENGINEERS (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' element, solid elasticity, steady state analysis, transient analysis. Students get a copy of all the source code published in the course textbook. Prerequisite: EGGN320. 3 hours lecture; 3 semester hours.

EGGN444. DESIGN OF STEEL STRUCTURES (I, II) To learn how to use the American Institute of Steel Construction/Load and Resistance Factor Design (AISC/LRFD) design specifications, to develop understanding of the underlying theory, and to learn basic steel structural member design principles to select the shape and size of a structural member. The design and analysis of tension members, compression members and flexural members is included, in addition to basic bolted and welded connection design. Prerequisite: EGGN342. 3 hours lecture; 3 semester hours.

EGGN445. DESIGN OF REINFORCED CONCRETE STRUCTURES (I, II) This course provides an introduction to the materials and principles involved in the design of reinforced concrete. It will allow students to develop an understanding of the fundamental behavior of reinforced concrete under compressive, tensile, bending, and shear loadings, and gain a working knowledge of strength design theory and its application to the design of reinforced concrete beams, columns, slabs, footings, retaining walls, and foundations. Prerequisite: EGGN342. 3 hours lecture; 3 semester hours.

EGGN448 ADVANCED SOIL MECHANICS (I) Advanced soil mechanics theories and concepts as applied to analysis and design in geotechnical engineering. Topics covered will include seepage, consolidation, shear strength and probabilistic methods. The course will have an emphasis on numerical solution techniques to geotechnical problems by finite elements and finite differences. Prerequisite: EGGN361. 3 hour lectures; 3 semester hours.

EGGN450. MULTIDISCIPLINARY ENGINEERING LABORATORY III (I, II) Laboratory experiments integrating electrical circuits, fluid mechanics, stress analysis, and other engineering fundamentals using computer data acquisition and transducers. Students will design experiments to gather data for solving engineering problems. Examples are recommending design improvements to a refrigerator, diagnosing and predicting failures in refrigerators, computer control of a hydraulic fluid power circuit in a fatigue test, analysis of structural failures in an off-road vehicle and redesign, diagnosis and prediction of failures in a motor/generator system. Prerequisites: DCGN381, EGGN250, EGGN352, EGGN350, EGGN351, EGGN320; concurrent enrollment in EGGN407. 3 hours lab; 1 semester hour.

EGGN451. HYDRAULIC PROBLEMS (I) Review of fundamentals, forces on submerged surfaces, buoyancy and flotation, gravity dams, weirs, steady flow in open channels, backwater curves, hydraulic machinery, elementary hydrodynamics, hydraulic structures. Prerequisite: EGGN351. 3 hours lecture; 3 semester hours.

EGGN/ESGN453. WASTEWATER ENGINEERING (I) The goal of this course is to familiarize students with the fundamental phenomena involved in wastewater treatment processes (theory) and the engineering approaches used in designing such processes (design). This course will focus on the physical, chemical and biological processes applied to liquid wastes of municipal origin. Treatment objectives will be discussed as the driving force for wastewater treatment. Prerequisite: ESGN353 or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN/ESGN454. WATER SUPPLY ENGINEERING (I) Water supply availability and quality. Theory and design of conventional potable water treatment unit processes. Design of distribution systems. Also includes regulatory analysis under the Safe Drinking Water Act (SDWA). Prerequisite: EGGN353, or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN/ESGN455. SOLID AND HAZARDOUS WASTE ENGINEERING (I) This course provides an introduction and overview of the engineering aspects of solid and hazardous waste management. The focus is on control technologies for solid wastes from common municipal and industrial sources and the end-of-pipe waste streams and process residuals that are generated in some key industries. Prerequisite: EGGN354. 3 hours lecture; 3 semester hours.

EGGN456. SCIENTIFIC BASIS OF ENVIRONMENTAL REGULATIONS (II) A critical examination of the experiments, calculations and assumptions underpinning numerical and narrative standards contained in federal and state environmental regulations. Top-down investigations of the historical development of selected regulatory guidelines and permitting procedures. Student directed design of improved regulations. Prerequisite: EGGN353 or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN/ESGN457. SITE REMEDIATION ENGINEERING (II) This course describes the engineering principles and practices associated with the characterization and remediation of contaminated sites. Methods for site characterization and risk assessment will be highlighted while the emphasis will be on remedial action screening processes and technology principles and conceptual design. Common isolation and containment and in situ and ex situ treatment technology will be covered. Computerized decision-support tools will be used and case studies will be presented. Prerequisite: EGGN354 or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN460. NUMERICAL METHODS FOR ENGINEERS(S) Introduction to the use of numerical methods in the solution of problems encountered in engineering analysis and design, e.g. linear simultaneous equations (e.g. analysis of elastic materials, steady heat flow); roots of nonlinear equations (e.g. vibration problems, open channel flow); eigen-value problems (e.g. natural frequencies, buckling and elastic stability); curve fitting and differentiation (e.g. interpretation of experimental data, estimation of gradients); integration (e.g. summation of pressure distributions, finite element properties, local averaging); ordinary differential equations (e.g. forced vibrations, beam bending) All course participants will receive source code consisting of a suite of numerical methods programs. Prerequisite: MACS 260 or 261, MACS315, EGGN320. 3 hours lecture; 3 semester hours.

EGGN464. FOUNDATIONS (I, II) Techniques of subsoil investigation, types of foundations and foundation problems, selection of basis for design of foundation types. Open-ended problem solving and decision making. Prerequisite: EGGN361. 3 hours lecture; 3 semester hours.

EGGN465. UNSATURATED SOIL MECHANICS (II) 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. Prerequisites: EGGN461 or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN471. HEAT TRANSFER (I, II) Engineering approach to conduction, convection, and radiation, including steady-state conduction, nonsteady-state conduction, internal heat generation conduction in one, two, and three dimensions, and combined conduction and convection. Free and forced convection including laminar and turbulent flow, internal and external flow. Radiation of black and grey surfaces, shape factors and electrical equivalence. Prerequisite: MACS315, EGGN351, EGGN371. 3 hours lecture; 3 semester hours.

EGGN473. FLUID MECHANICS II (I) Review of elementary fluid mechanics and engineering. Two-dimensional internal and external flows. Steady and unsteady flows. Fluid engineering problems. Compressible flow. Computer solutions of various practical problems for mechanical and related engineering disciplines. Prerequisite: EGGN351 or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN478. ENGINEERING DYNAMICS (I) Applications of dynamics to design, mechanisms and machine elements. Kinematics and kinetics of planar linkages. Analytical and graphical methods. Four-bar linkage, slider-crank, quick-return mechanisms, cams, and gears. Analysis of nonplanar mechanisms. Static and dynamic balancing of rotating machinery. Free and forced vibrations and vibration isolation. Prerequisite: EGGN315; concurrent enrollment in MACS315. 3 hours lecture; 3 semester hours.

EGGN482. MICROCOMPUTER ARCHITECTURE AND INTERFACING (I) Microprocessor and microcontroller architecture focusing on hardware structures and elementary machine and assembly language programming skills essential for use of microprocessors in data acquisition, control, and instrumentation systems. Analog and digital signal conditioning, communication, and processing. A/D and D/A converters for microprocessors. RS232 and other communication standards. Laboratory study and evaluation of microcomputer system; design and implementation of interfacing projects. Prerequisite: EGGN384 or consent of instructor. 3 hours lecture; 3 hours lab; 4 semester hours.

EGGN483. ANALOG & DIGITAL COMMUNICATION SYSTEMS (II) Signal classification; Fourier transform; filtering; sampling; signal representation; modulation; demodulation; applications to broadcast, data transmission, and instrumentation. Prerequisite: EGGN388 or consent of instructor. 3 hours lecture; 3 hours lab; 4 semester hours.

EGGN484. POWER SYSTEMS ANALYSIS (I) 3-phase power systems, per-unit calculations, modeling and equivalent circuits of major components, voltage drop, fault calculations, symmetrical components and unsymmetrical faults, system grounding, power-flow, selection of major equipment, design of electric power distribution systems. Prerequisite: EGGN389. 3 hours lecture; 3 semester hours.

EGGN485. INTRODUCTION TO HIGH POWER ELECTRONICS (II) Power electronics are used in a broad range of applications from control of power flow on major transmission lines to control of motor speeds in industrial facilities and electric vehicles, to computer power supplies. This course introduces the basic principles of analysis and design of circuits utilizing power electronics, including AC/DC, AC/AC, DC/DC, and DC/AC conversions in their many configurations. Prerequisites: EGGN385, EGGN389. 3 hours lecture; 3 semester hours.

EGGN486. PRACTICAL DESIGN OF SMALL RENEWABLE ENERGY SYSTEMS (I) This course provides the fundamentals to understand and analyze renewable energy powered electric circuits. It covers practical topics related to the design of alternative energy based systems. It is assumed the students will have some basic and broad knowledge of the principles of electrical machines, thermodynamics, electronics, and fundamentals of electric power systems. One of

the main objectives of this course is to focus on the interdisciplinary aspects of integration of the alternative sources of energy, including hydropower, wind power, photovoltaic, and energy storage for those systems. Power electronic systems will be discussed and how those electronic systems can be used for stand-alone and grid-connected electrical energy applications. Prerequisite: EGGN382 or consent of instructor. 3 hours lecture; 3 semester hours.

EGGN 487. ADVANCED ELECTRIC POWER SYSTEMS LABORATORY (II) Electric power grid or the interconnected power network is one of the most complex systems. Evaluating the system operation and planning for future expansion, reliability and security analysis has become increasingly more complex. The common techniques utilized in the design includes commercially available software. The PowerWorld Simulator is one of the most commonly used such software and will be featured in this class. Emphasis will be focused on determining how the power flow within a large system is controlled and understanding the factors that influence voltage regulation and reactive power control. Contingency analysis, evaluating system improvements, and planning for future expansion will also be featured. Short circuit currents resulting from symmetrical and unsymmetrical faults will also be calculated. Prerequisites: EGGN 484 and/or consent of instructor. 3 hours laboratory; 1 semester hour.

EGGN488. RELIABILITY OF ENGINEERING SYSTEMS (I) This course addresses uncertainty modeling, reliability analysis, risk assessment, reliability-based design, predictive maintenance, optimization, and cost-effective retrofit of engineering systems such as structural, sensory, electric, pipeline, hydraulic, lifeline and environmental facilities. Topics include introduction of reliability of engineering systems, stochastic engineering system simulation, frequency analysis of extreme events, reliability and risk evaluation of engineering systems, and optimization of engineering systems. Prerequisite: MACS323. 3 hours lecture; 3 semester hours.

EGGN491. SENIOR DESIGN I (I, II) (WI) This course is the first of a two-semester capstone course sequence giving the student experience in the engineering design process. Realistic open-ended design problems are addressed for real world clients at the conceptual, engineering analysis, and the synthesis stages and include economic and ethical considerations necessary to arrive at a final design. Students are assigned to interdisciplinary teams and exposed to processes in the areas of design methodology, project management, communications, and work place issues. Strong emphasis is placed on this being a process course versus a project course. This is a writing-across-the-curriculum course where students' written and oral communication skills are strengthened. The design projects are chosen to develop student creativity, use of design methodology and application of prior course work paralleled by individual study and re-

search. Prerequisite: Students must have completed the summer field session associated with their specialty area prior to entering Senior Design I. 1-2 hour lecture; 6 hours lab; 3 semester hours

EGGN492. SENIOR DESIGN II (I, II) (WI) This course is the second of a two-semester sequence to give the student experience in the engineering design process. Design integrity and performance are to be demonstrated by building a prototype or model, or producing a complete drawing and specification package, and performing pre-planned experimental tests, wherever feasible, to verify design compliance with client requirements. Prerequisite: EGGN491. 1 hour lecture; 6 hours lab; 3 semester hours.

EGGN498. SPECIAL TOPICS IN ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

EGGN499. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Environmental Science and Engineering

ROBERT L. SIEGRIST, Professor and Division Director
BRUCE D. HONEYMAN, Professor
TISSA ILLANGASEKARE, Professor and AMAX Distinguished Chair
PHILIPPE ROSS, Professor
RONALD R.H. COHEN, Associate Professor
JÖRG DREWES, Associate Professor
LINDA A. FIGUEROA, Associate Professor
JUNKO MUNAKATA MARR, Associate Professor
JOHN E. McCRAY, Associate Professor
TZAHI CATH, Assistant Professor
JOHN R. SPEAR, Assistant Professor
ROBERT F. HOLUB, Research Professor
MICHAEL SEIBERT, Research Professor
MARIA L. GHIRARDI, Research Associate Professor
MATTHIAS KOHLER, Research Associate Professor
MICHELLE CRIMI, Research Assistant Professor
MATTHEW C. POSEWITZ, Research Assistant Professor
PEI XU, Research Assistant Professor
KATHRYN LOWE, Senior Research Associate
JILL M.B. TOMARAS, Research Associate

Program Description

The Environmental Science and Engineering (ESE) Division offers specialty and minor programs in Environmental Science and Engineering. ESE provides an undergraduate curriculum leading to a Minor (18 hours) or an Area of Special Interest (ASI) (12 hours).

Environmental Engineering Specialty in the Engineering Division

The Environmental Engineering Specialty introduces students to the fundamentals of environmental engineering including the scientific and regulatory basis of public health and environmental protection. Topics covered include environmental science and regulatory processes, water and wastewater engineering, solid and hazardous waste management, and contaminated site remediation.

See entries in this Bulletin under Engineering (pg. 48) and the degree program leading to the BS in Engineering with a Specialty in Environmental Engineering. This undergraduate Specialty is supported by the Environmental Science and Engineering Division.

Environmental Science and Engineering Minor and ASI

General Requirements:

A **Minor Program** of study must consist of a minimum of 18 credit hours of a logical sequence of courses, only three hours of which may be taken at the 100- or 200- level.

An **Area of Special Interest** (ASI) must consist of a minimum of 12 credit hours of a logical sequence of courses, only three hours of which may be taken at the 100- or 200-level.

A **Minor Program / Area of Special Interest** declaration (available in the Registrar's Office) should be submitted for approval prior to the student's completion of half of the hours proposed to constitute the program. Approvals are required from the Director of the Environmental Science and Engineering Division, the student's advisor, and the Department Head or Division Director in the department or division in which the student is enrolled.

All students pursuing the ESE Minor or ASI are required to take ESGN/EGGN353 and ESGN/EGGN354.

Additional courses for the ASI or Minor sequence must be selected from:

ESGN401 Fundamentals of Ecology
ESGN440A Environmental Pollution: Sources, Characteristics, Transport and Fate
ESGN/EGGN453 Wastewater Engineering
ESGN/EGGN454 Water Supply Engineering
ESGN/EGGN456 Scientific Basis of Environmental Regulations
ESGN/EGGN457 Site Remediation Engineering
ESGN462 Solid Waste Minimization and Recycling
ESGN463 Pollution Prevention: Fundamentals and Practice

Combined Degree Program Option

CSM Undergraduate students have the opportunity to begin work on a M.S. degree in Environmental Science and Engineering 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 see the ESE Division website: <http://www.mines.edu/academic/envsci/ucombine.html>.

Description of Courses

Undergraduate Courses

ESGN198. SPECIAL TOPICS IN ENVIRONMENTAL SCIENCE AND ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

ESGN199. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

ESGN298. SPECIAL TOPICS IN ENVIRONMENTAL SCIENCE AND ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

ESGN299. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: *Independent Study* form must be complete and submitted to the Registrar. Variable credit: 1-6.

ESGN/SYGN203. NATURAL AND ENGINEERED ENVIRONMENTAL SYSTEMS Introduction to natural and engineered environmental systems analysis. Environmental decision making, sustainable development, pollution sources, effects and prevention, and environmental life cycle assessment. The basic concepts of material balances, energy balances, chemical equilibrium and kinetics and structure and function of biological systems will be used to analyze environmental systems. Case studies in sustainable development, industrial ecology, pollution prevention and life cycle assessment will be covered. The goal of this course is to develop problem-solving skills associated with the analysis of environmental systems. Prerequisites: CHGN124 or concurrent; MACS112 or concurrent; PHGN 100; SYGN101. 3 semester hours.

ESGN301/BELS301. GENERAL BIOLOGY I (I) This is the first semester an introductory course in Biology. Emphasis is placed on the methods of science; structural, molecular, and energetic basis of cellular activities; genetic variability and evolution; diversity and life processes in plants and animals; and, principles of ecology. Prerequisite: None. 3 hours lecture; 3 semester hours.

ESGN303/BELS303. GENERAL BIOLOGY II (II) This is the continuation of General Biology I. Emphasis is placed on an examination of organisms as the products of evolution. The diversity of life forms will be explored. Special attention will be given to the vertebrate body (organs, tissues and systems) and how it functions. Prerequisite: General Biology I, or equivalent. 3 hours lecture; 3 semester hours.

ESGN311/BELS311. GENERAL BIOLOGY I LABORATORY (I) This course provides students with laboratory exercises that complement lectures given in ESGN301/BELS301, the first semester introductory course in Biology. Emphasis is placed on the methods of science; structural, molecular, and energetic basis of cellular activities; genetic variability and evolution; diversity and life processes in plants and animals; and, principles of ecology. Offered with the collaboration of Red Rocks Community College. Corequisite or Prerequisite: ESGN/BELS301 or equivalent. 3 hours laboratory; 1 semester hour.

ESGN313/BELS313. GENERAL BIOLOGY II LABORATORY (II) This course provides students with laboratory exercises that complement lectures given in ESGN303/BELS303, the second semester introductory course in Biology. Emphasis is placed on an examination of organisms as the products of evolution. The diversity of life

forms will be explored. Special attention will be given to the vertebrate body (organs, tissues and systems) and how it functions. Offered with the collaboration of Red Rocks Community College. Co-requisite or Prerequisite:

ESGN/BELS303 or equivalent. 3 hours laboratory; 1 semester hour.

ESGN321/BELS321. INTRODUCTION TO GENETICS (II)

A study of the mechanisms by which biological information is encoded, stored, and transmitted, including Mendelian genetics, molecular genetics, chromosome structure and rearrangement, cytogenetics, and population genetics. Prerequisite: General Biology I or equivalent. 3 hours lecture + 3 hours laboratory; 4 semester hours.

ESGN/EGGN353. FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I (I, II)

Topics covered include history of water related environmental law and regulation, major sources and concerns of water pollution, water quality parameters and their measurement, material and energy balances, water chemistry concepts, microbial concepts, aquatic toxicology and risk assessment. Prerequisite: Junior standing or consent of instructor. 3 hours lecture; 3 semester hours.

ESGN/EGGN354. FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING II (II)

Introductory level fundamentals in atmospheric systems, air pollution control, solid waste management, hazardous waste management, waste minimization, pollution prevention, role and responsibilities of public institutions and private organizations in environmental management (relative to air, solid and hazardous waste. Prerequisite: Junior standing or consent of instructor. 3 hours lecture; 3 semester hours.

ESGN398. SPECIAL TOPICS IN ENVIRONMENTAL SCIENCE AND ENGINEERING (I, II)

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Consent of instructor. Variable credit: 1-6 semester hours.

ESGN399. INDEPENDENT STUDY (I, II)

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

ESGN401. FUNDAMENTALS OF ECOLOGY (I)

Biological and ecological principles discussed and industrial examples of their use given. Analysis of ecosystem processes, such as erosion, succession, and how these processes relate to engineering activities, including engineering design and plant operation. Criteria and performance standards analyzed for facility siting, pollution control, and mitigation of impacts. North American ecosystems analyzed. Concepts of forestry, range, and wildlife management integrated as they

apply to all the above. Three to four weekend field trips will be arranged during the semester. 3 hours lecture; 3 semester hours.

ESGN402/BELS402. CELL BIOLOGY AND PHYSIOLOGY (II)

An introduction to the morphological, biochemical and biophysical properties of cells and their significance in the life processes. Prerequisite: General Biology I, or equivalent. 3 hours lecture; 3 semester hours.

ESGN403/CHGN403. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY (I)

Processes by which natural and anthropogenic chemicals interact, react and are transformed and redistributed in various environmental compartments. Air, soil and aqueous (fresh and saline surface and groundwaters) environments are covered, along with specialized environments such as waste treatment facilities and the upper atmosphere. Prerequisites: SYGN101, DCGN209, and CHGN222. 3 hours lecture; 3 semester hours.

ESGN440. ENVIRONMENTAL POLLUTION: SOURCES, CHARACTERISTICS, TRANSPORT AND FATE (I)

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: EGGN353 or consent of instructor. 3 hours lecture; 3 semester hours.

ESGN/EGGN453. WASTEWATER ENGINEERING (I)

The goal of this course is to familiarize students with the fundamental phenomena involved in wastewater treatment processes (theory) and the engineering approaches used in designing such processes (design). This course will focus on the physical, chemical and biological processes applied to liquid wastes of municipal origin. Treatment objectives will be discussed as the driving force for wastewater treatment. Prerequisite: ESGN353 or consent of instructor. 3 hours lecture; 3 semester hours.

ESGN/EGGN454. WATER SUPPLY ENGINEERING (II)

Water supply availability and quality. Theory and design of conventional potable water treatment and processes. Design of distribution systems. Also includes regulatory analysis under the Safe Drinking Water Act (SDWA). Prerequisite: EGGN353 or consent of instructor. 3 hours lecture; 3 semester hours.

ESGN/EGGN455. SOLID AND HAZARDOUS WASTE ENGINEERING (II) This course provides an introduction and overview of the engineering aspects of solid and hazardous waste management. The focus is on control technologies for solid wastes from common municipal and industrial sources and the end-of-pipe waste streams and process residuals that are generated in some key industries. Prerequisite: EGGN354. 3 hours lecture; 3 semester hours.

ESGN/EGGN456. SCIENTIFIC BASIS OF ENVIRONMENTAL REGULATIONS (I) A critical examination of the experiments, calculations and assumptions underpinning numerical and narrative standards contained in federal and state environmental regulations. Top-down investigations of the historical development of selected regulatory guidelines and permitting procedures. Student directed design of improved regulations. Prerequisite: EGGN353. 3 hours lecture; 3 semester hours.

ESGN/EGGN457. SITE REMEDIATION ENGINEERING (II) This course describes the engineering principles and practices associated with the characterization and remediation of contaminated sites. Methods for site characterization and risk assessment will be highlighted while the emphasis will be on remedial action screening processes and technology principles and conceptual design. Common isolation and containment and in-situ and ex-situ treatment technology will be covered. Computerized decision-support tools will be used and case studies will be presented. Prerequisites: EGGN353, EGGN354 or consent of instructor. 3 hours lecture; 3 semester hours.

ESGN462/MTGN462. SOLID WASTE MINIMIZATION AND RECYCLING (I) This course will examine, using case studies, how industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisites: EGGN/ESGN353, EGGN/ESGN354, and ESGN302/CHGN403 or consent of instructor. 3 hours lecture; 3 semester hours.

ESGN463. POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE (II) 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. Prerequisite: EGGN/ESGN353 or EGGN/ESGN354 or consent of instructor. 3 hours lecture; 3 semester hours.

ESGN490. ENVIRONMENTAL LAW (I) Specially designed for the needs of the environmental quality engineer, scientist, planner, manager, government regulator, consultant, or advocate. Highlights include how our legal system works, environmental law fundamentals, all major US EPA/state enforcement programs, the National Environmental Policy Act, air and water pollutant laws, risk assessment and management, and toxic and hazardous substance laws (RCRA, CERCLA, TSCA, LUST, etc). Prerequisites: ESGN353 or ESGN354, or consent of instructor. 3 hours lecture; 3 semester hours.

ESGN498. SPECIAL TOPICS IN ENVIRONMENTAL SCIENCE AND ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

ESGN499. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Geology and Geological Engineering

MURRAY W. HITZMAN, Professor, Charles F. Fogarty Professor of Economic Geology, and Department Head

JOHN B. CURTIS, Professor

WENDY J. HARRISON, Professor

EILEEN POETER, Professor

SAMUEL B. ROMBERGER, Professor

RICHARD F. WENDLANDT, Professor

DAVID A. BENSON, Associate Professor

L. GRAHAM CLOSS, Associate Professor

JERRY D. HIGGINS, Associate Professor

JOHN D. HUMPHREY, Associate Professor and Acting Department Head (2006/2007)

KEVIN W. MANDERNACK, Associate Professor (also Chemistry and Geochemistry)

JOHN E. McCRAY, Associate Professor

ERIC P. NELSON, Associate Professor

PIRET PLINK-BJORKLUND, Associate Professor

PAUL SANTI, Associate Professor

BRUCE TRUDGILL, Associate Professor

MICHAEL N. GOOSEFF, Assistant Professor

CHRISTIAN V. SHOREY, Instructor

CHARLES F. KLUTH, Distinguished Scientist

JEFFREY W. HEDENQUIST, Research Associate Professor

DONNA S. ANDERSON, Research Assistant Professor

MARY CARR, Research Assistant Professor

GEOFF THYNE, Research Assistant Professor

THOMAS L.T. GROSE, Professor Emeritus

JOHN D. HAUN, Professor Emeritus

RICHARD W. HUTCHINSON, Professor Emeritus

KEENAN LEE, Professor Emeritus

A. KEITH TURNER, Professor Emeritus

JOHN E. WARME, Professor Emeritus

ROBERT J. WEIMER, Professor Emeritus

TIMOTHY A. CROSS, Associate Professor Emeritus

GREGORY S. HOLDEN, Associate Professor Emeritus and Assistant Department Head

Program Description

A Bachelor of Science degree in Geological Engineering is the basis for careers concentrating on the interaction of humans and the earth. Geological Engineers deal with a wide variety of the resource and environmental problems that come with accommodating more and more people on a finite planet. Geologic hazards and conditions must be recognized and considered in the location and design of foundations for buildings, roads and other structures; waste disposal facilities must be properly located, designed and constructed; contaminated sites and ground water must be accurately characterized before cleanup can be accomplished; water supplies must be located, developed and protected; and new mineral and energy resources must be located and developed in an environmentally sound manner. Geological Engineers are the professionals trained to meet these challenges.

The Geological Engineering curriculum provides a strong foundation in the basic sciences, mathematics, geological sci-

ence and basic engineering along with specialized upper level instruction in integrated applications to real problems. Engineering design is integrated throughout the four year program, beginning in Design I (Freshman year) and ending with the capstone design courses in the senior year. The program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700. Students have the background to take the Fundamentals of Engineering Exam, the first step in becoming a registered Professional Engineer.

Graduates follow five general career paths:

Engineering Geology and Geotechnics. Careers in site investigation, design and stabilization of foundations or slopes; site characterization, design, construction and remediation of waste disposal sites or contaminated sites; and assessment of geologic hazards for civil, mining or environmental engineering projects.

Ground-Water Engineering. Careers in assessment and remediation of ground-water contamination, design of ground-water control facilities for geotechnical projects and exploration for and development of ground-water supplies.

Petroleum Exploration and Development Engineering. Careers in search for and development of oil, gas and coal and their efficient extraction.

Mineral Exploration and Development Engineering. Careers in search for and development of natural deposits of metals, industrial materials and rock aggregate.

Geological Science. Students are also well prepared to pursue careers in basic geoscience. Graduates have become experts in fields as divergent as global climate change, the early history of the Earth, planetary science, fractal representation of ground-water flow and simulation of sedimentary rock sequences, to name a few. Careers are available in research and education.

The curriculum may be followed along two concentration paths with slightly different upper division requirements. Both concentrations are identical in the first two years as students study basic science, mathematics, engineering science, and geological science. In the junior year those students pursuing careers in ground-water engineering, engineering geology and geotechnics, or geoenvironmental engineering applications follow the Environmental, Engineering Geology and Geotechnics, and Ground-Water Engineering Concentration. Students anticipating careers in resource exploration and development or who expect to pursue graduate studies in geological sciences follow the Mineral and Petroleum Exploration Engineering Concentration.

At all levels the Geological Engineering Program emphasizes laboratory and field experience. All courses have a laboratory session, and after the junior year students participate in a field course, which is six weeks of geologic and engi-

neering mapping and direct observation. The course involves considerable time outdoors in the mountains and canyons of Utah and southwestern Colorado.

At the senior level, students begin to focus on a career path by taking course sequences in at least two areas of geological engineering specialization. The course sequences begin with a 4 unit course in the fundamentals of a field of geological engineering which is followed by a 3 unit design-oriented course that emphasizes experience in direct application of principles through design projects.

Students interested in careers in Geological Engineering are encouraged to enroll in a one unit Spring course (GEOL102) entitled "Careers in Geological Engineering." The course, a series of presentations by faculty and outside professionals on all aspects of these careers, is designed to provide students with the background necessary to make informed career decisions. All students are invited to participate.

Program Educational Objectives (Bachelor of Science in Geological Engineering)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the Geological Engineering Program at CSM has established the following program educational objectives:

Graduates of the Department should have depth and breadth in one or more of the following fields: ground-water engineering, engineering geology and geotechnics, environmental geology, and natural resource exploration and development. They should have the knowledge and experience to recognize problems and design solutions through application of scientific and engineering principles and methods.

Graduates must have the communication skills which permit them to convey technical information, geoscience and geoengineering concepts, and results of technical studies to peers and the lay public. Communication skills include oral, written and graphic presentations, computer-based retrieval, manipulation and analysis of technical information, and general computer literacy.

Graduates should appreciate and respect the characteristics and worth of leadership and teamwork, and should possess the attitude that teamwork and cooperation are equally important values as leadership.

Graduates should have the skills and desire, as well as technical breadth and depth, to continue their personal and professional growth through life-long learning. Graduates should have the understanding that personal and professional flexibility, creativity, resourcefulness, receptivity and openness are crucial attributes to continued growth and success in increasingly diverse, multi-disciplinary technical environments.

Graduates should appreciate and respect diversity of culture, language, religion, social-political-economic systems,

approaches toward thinking and analysis, and personal preference. They should feel capable of working in a technical capacity and communicating with others in an international geoscience and geoengineering arena.

Graduates should practice ethical behavior and integrity, and they should function such that their society benefits from their work in the geosciences and geoengineering disciplines.

Program Requirements

In order to achieve the program goals listed above, every student working towards the Bachelor of Science Degree in Geological Engineering must complete the following requirements:

Degree Requirements (Geological Engineering)

Sophomore Year Fall Semester		lec.	lab.	sem.hrs.
GEGN202	Geol. Principles & Processes	3	3	4
MACS213	Calc. for Scientists & Engr's III	4		4
DCGN241	Statics	3		3
SYGN200	Human Systems	3		3
PAGN201	Physical Education III		2	0.5
Total				14.5

Sophomore Year Spring Semester		lec.	lab.	sem.hrs.
EPIC251	GIS Epics II	2	3	3
GEGN206	Earth Materials	2	3	3
MACS315	Differential Equations	3		3
PHGN200	Physics II	3.5	3	4.5
EGGN320	Mechanics of Materials	3		3
PAGN202	Physical Education IV		2	0.5
Total				17

Following the sophomore year, Geological Engineering students choose from one of two concentrations: 1. Minerals and Petroleum Exploration Engineering 2. Environmental, Engineering Geology and Geotechnics, and Ground-water Engineering

Minerals and Petroleum Exploration Engineering Concentration

Recommended for students intending careers in exploration and development of mineral and fuels resources, or intending careers in geoscience research and education.

Junior Year Fall Semester		lec.	lab.	sem.hrs.
GEOL309	Structural Geology	3	3	4
GEOL321	Mineralogy & Mineral Characterization	2	3	3
DCGN209	Thermodynamics	3		3
EBGN201	Principles of Economics	3		3
EGGN361	Soil Mechanics OR	3		3
MNGN321	Introduction to Rock Mechanics*	2	3	3
Total				16

Junior Year Spring Semester		lec.	lab.	sem.hrs.
GEOL307	Petrology	2	3	3
GEGN317	Field Methods		6	2
GEOL314	Stratigraphy	3	3	4
LAIS/EBGN	H&SS Cluster Elective I	3		3
Tech Elective II *		3		3
EGGN351	Fluid Mechanics	3		3
Total				18

*Technical Electives I & II: Either MNGN321 or EGGN361 is required as ONE of the technical electives. An additional technical

elective must be selected so that the total technical elective credit hours are composed of a balance of engineering science and engineering design.

Summer Field Term			
	lec.	lab.	sem.hrs.
GEGN316 Field Geology		6	6
Senior Year Fall Semester			
	lec.	lab.	sem.hrs.
GEGN4— Option Elective	3	3	4
GEGN4— Option Elective	3	3	4
GEGN432 Geological Data Management	1	6	3
LAIS/EBGN H&SS Cluster Elective II	3		3
Free Elective			3
Total			17
Senior Year Spring Semester			
	lec.	lab.	sem.hrs.
GEGN4— Design Elective	2	3	3
GEGN4— Design Elective	2	3	3
LAIS/EBGN H&SS Cluster Elective III	3		3
Free Elective			3
Free Elective			3
Total			15
Degree Total			136.5

Option Electives:

Students must take TWO of the following four courses.

GEGN401 Mineral Deposits	4 credits
GEGN438 Petroleum Geology	4 credits
GEGN467 Ground-Water Engineering	4 credits
GEGN468 Engineering Geology & Geotechnics	4 credits

Design Electives:

Students must take TWO design courses, corresponding in subject area to the Option Elective.

GEGN403 Mineral Exploration Design	3 credits
GEGN439 Multi-Disciplinary Petroleum Design	3 credits
GEGN469 Engineering Geology Design	3 credits
GEGN470 Ground-Water Engineering Design	3 credits

Environmental, Engineering Geology and Geotechnics, and Ground-Water Engineering Concentration

Recommended for students intending careers in geotechnical engineering, hydrogeology, or other environmental engineering careers.

Junior Year Fall Semester			
	lec.	lab.	sem.hrs.
GEOL309 Structural Geology	3	3	4
DCGN209 Introduction to Thermodynamics	3		3
or			
EGGN371 Thermodynamics	3		3
EBGN201 Principles of Economics	3		3
EGGN361 Soil Mechanics	3		3
EGGN363 Soil Mechanics Lab		1	1
EGGN351 Fluid Mechanics	3		3
Total			17
Junior Year Spring Semester			
	lec.	lab.	sem.hrs.
GEGN317 Field Methods		6	2
GEGN473 Site Investigation	3		3
GEOL314 Stratigraphy	3	3	4
LAIS/EBGN H&SS Cluster Elective I	3		3
MNGN321 Rock Mechanics	2	3	3
Total			15

Summer Field Term			
	lec.	lab.	sem.hrs.
GEGN316 Field Geology		6	6

Senior Year Fall Semester			
	lec.	lab.	sem.hrs.
GEGN468 Engineering Geology	3	3	4
GEGN467 Ground-Water Engineering	3	3	4
GEGN432 Geological Data Management	1	6	3
LAIS/EBGN H&SS Cluster Elective II	3		3
Free Elective	3		3
Total			17

Senior Year Spring Semester			
	lec.	lab.	sem.hrs.
GEGN469 Engineering Geology Design	3		3
GEGN470 Ground-Water Engineering Design	3		3
LAIS/EBGN H&SS Cluster Elective III	3		3
Free Elective	3		3
Free Elective	3		3
Total			15

Degree Total 134.5

Students in the Environmental, Engineering Geology and Geotechnics, and Ground-Water Engineering Concentration may further specialize by utilizing their free elective courses to emphasize a specific specialty. Suggested courses are presented below and should be selected in consultation with the student's advisor. The emphasis area is an informal designation only and it will not appear on the transcript.

Engineering Geology and Geotechnics Emphasis:

EGGN464 Foundations
GEGN475 Applications of Geographic Information Systems
EBGN321 Engineering Economics
EGGN465 Unsaturated Soil Mechanics
GEGN399 Independent Study in Engineering Geology
GEGN476 Desktop Mapping Applications for Project Data Management
GEGN499 Independent Study in Engineering Geology
GEOL307 Petrology
GEOL321 Mineralogy & Mineral Characterization
MACS261 Programming Concepts
MNGN404 Tunneling
MNGN408 Underground Design and Construction
MNGN410 Excavation Project Management
MNGN445/545 Rock Slope Design

Water Engineering Emphasis:

EBGN321 Engineering Economics
EGGN/ESGN353 Fundamentals of Environmental Sci. & Engr. I
EGGN/ESGN354 Fundamentals of Environmental Sci. & Engr. II
EGGN451 Hydraulic Problems
EGGN465 Unsaturated Soil Mechanics
EGGN473 Fluid Mechanics
EGGN/ESGN453 Wastewater Engineering
EGGN/ESGN454 Water Supply Engineering
ESGN401 Fundamentals of Ecology
ESGN440 Environmental Pollution
ESGN/EGGN455 Solid & Hazardous Waste Engineering
ESGN/EGGN456 Scientific Basis of Environmental Regulations
ESGN/EGGN457 Site Remediation Engineering
ESGN490 Environmental Law
ESGN/CHGN403 Intro. to Environmental Chemistry
GEGN499 Independent Study in Hydrogeology

GEGN475 Applications of Geographic Information Systems
 GEGN481 Advanced Hydrology
 GEGN483 Math Modeling of Ground-Water Systems
 GEOL321 Mineralogy & Mineral Characterization
 GPGN311 Survey of Exploration Geophysics
 LAIS487 Environmental Politics & Policy
 LAIS488 Water Politics & Policy
 MACS260 Fortran Programming
 MACS261 Programming Concepts
 MACS332 Linear Algebra
 MACS333 Intro to Mathematical Modeling

Geological Engineering Minor

Students, other than Geological Engineering majors, desiring to receive a minor in Geological Engineering must complete 18 hours of Geology and Geological Engineering courses as follows:

1. SYGN101 Earth and Environmental Systems
2. At least one course from each of the following groups:
 - Earth Materials*
 - GEGN206 Earth Materials
 - Structural Geology*
 - GEOL308 Applied Structural Geology or
 - GEOL309 Structural Geology and Tectonics
 - Stratigraphy*
 - GEOL314 Stratigraphy or
 - GEOL315 Sedimentology and Stratigraphy
3. One senior area elective course can be chosen from the following:
 - GEGN401 Mineral Deposits
 - GEGN438 Petroleum Geology
 - GEGN467 Ground-Water Engineering
 - GEGN468 Engineering Geology & Geotechnics
4. Elective Geology & Geological Engineering courses to total 18 credits. (Design electives listed below are strongly recommended.)
 - GEGN403 Mineral Exploration Design
 - GEGN439 Multi-Disciplinary Petroleum Design
 - GEGN469 Engineering Geology Design
 - GEGN470 Ground-Water Engineering Design

Area of Special Interest

An Area of Special Interest (ASI) consists of 12 or more hours of course work. To receive an ASI, a student must take at least 12 hours of a logical sequence of courses, only three credit hours of which may be at the 100- or 200- level. Additionally a total of not more than three credit hours of the sequence may be specifically required by the degree program in which the student is graduating. For Geological Engineering, ASI students must satisfy item 2 of the Geological Engineering minor requirements above, or gain written approval of an alternative program.

Description of Courses

Freshman Year

GEOL102. INTRODUCTION TO GEOLOGICAL ENGINEERING (II) Presentations by faculty members and outside professionals of case studies to provide a comprehensive overview of the fields of Geology and Geological Engineering and the preparation necessary to pursue careers in those fields. A short paper on an academic professional path will be required. Prerequisite: SYGN101 or concurrent enrollment. 1 hour lecture; 1 semester hour.

GEGN/GEOL198. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING (I, II) Special topics classes taught on a one-time basis. May include lecture, laboratory and field trip activities. Prerequisite: Approval of instructor and department head. Variable credit; 1 to 6 semester hours.

GEGN199. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY (I, II) Individual special studies, laboratory and/or field problems in geological engineering or engineering hydrogeology. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

GEOL199. INDEPENDENT STUDY IN GEOLOGY (I, II) Individual special studies, laboratory and/or field problems in geology. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Sophomore Year

GEGN 202. GEOLOGIC PRINCIPLES AND PROCESSES (I) Introduction to principles of geomorphology and historical geology. Geomorphology of glacial, volcanic, arid, karst, and complex geological landscapes. Introduction to weathering, soils, hillslopes, and drainage systems. Geologic time scale and deep time, stratigraphic principles, evolution and the fossil record, geochronology, plate tectonics, and critical events in Earth history. Laboratories emphasize fieldwork in geomorphic regions of Colorado, map skills, time and ordering of geologic events, and fossil preservation and identification. Prerequisite: SYGN 101, 3 hours lecture, 3 hours lab: 4 semester hours.

GEGN206. EARTH MATERIALS (II) Introduction to Earth Materials, emphasizing the structure, formation, and behavior of minerals and rocks. Laboratories emphasize the recognition, description, and engineering evaluation of earth materials. Prerequisite: SYGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN/GEOL298. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING (I, II) Special topics classes taught on a one-time basis. May include lecture, laboratory and field trip activities. Prerequisite: Approval of instructor and department head. Variable credit; 1 to 6 semester hours.

GEGN299. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY (I, II) Individual special studies, laboratory and/or field problems in geological engineering or engineering hydrogeology. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 semester hours.

GEOL299. INDEPENDENT STUDY IN GEOLOGY (I, II) Individual special studies, laboratory and/or field problems in geology. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 semester hours.

Junior Year

GEGN307. PETROLOGY (II) An introduction to igneous, sedimentary and metamorphic processes, stressing the application of chemical and physical mechanisms to study the origin, occurrence, and association of rock types. Emphasis on the megascopic and microscopic classification, description, and interpretation of rocks. Analysis of the fabric and physical properties. Prerequisite: GEOL321, DCGN209. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL308. INTRODUCTORY APPLIED STRUCTURAL GEOLOGY (II) Nature and origin of structural features of Earth's crust emphasizing oil entrapment and control of ore deposition. Structural patterns and associations are discussed in context of stress/strain and plate tectonic theories, using examples of North American deformed belts. Lab and field projects in structural geometry, map air photo and cross section interpretation, and structural analysis. Course required of all PEGN and MNGN students. Prerequisite: SYGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL309. STRUCTURAL GEOLOGY AND TECTONICS (I) (WI) Recognition, habitat, and origin of deformational structures related to stresses and strains (rock mechanics and microstructures) and modern tectonics. Structural development of the Appalachian and Cordilleran systems. Comprehensive laboratory projects use descriptive geometry, stereographic projection, structural contours, map and air photo interpretation, structural cross section and structural pattern analysis. Required of Geological and Geophysical Engineers. Prerequisite: SYGN101, GEGN 202 and GEGN 206 or GPGN210. 3 hours lecture, 3 hours lab; 4 semester hours.

GEOL 310. EARTH MATERIALS AND RESOURCES (II) Introduction to Earth Materials, emphasizing the structure, formation, distribution and engineering behavior of minerals, rocks and ores. Laboratories emphasize the recognition, description and engineering evaluation of natural materials. Lectures present the knowledge of natural materials, processes and resources necessary for mining engineering careers. Prerequisite: SYGN 101. 3 hours lecture, 3 hours lab; 4 semester hours.

GEOL 311. STRUCTURAL GEOLOGY FOR MINING ENGINEERS (I) Nature and origin of structural features of Earth's crust emphasizing structural controls of ore deposits

and analysis of structures related to rock engineering and mining. Structural features and processes are related to stress/strain theory and rock mechanics principles. Lab and field projects include deformation experiments, geologic map, cross section, and orientation data analysis of structural features including fractures, faults, folds, and rock cleavages. Prerequisite: SYGN 101. 2 semester hours combined lecture and lab.

GEOL314. STRATIGRAPHY (II) Lectures and laboratory and field exercises in concepts of stratigraphy and biostratigraphy, facies associations in various depositional environments, sedimentary rock sequences and geometries in sedimentary basins, and geohistory analysis of sedimentary basins. Prerequisite: SYGN101, GEOL202. 3 hours lecture, 3 hours lab; 4 semester hours.

GEOL315. SEDIMENTOLOGY AND STRATIGRAPHY (I) Integrated lecture, laboratory and field exercises on the genesis of sedimentary rocks as related to subsurface porosity and permeability development and distribution for non-geology majors. Emphasis is placed on siliciclastic systems of varying degrees of heterogeneity. Topics include diagenesis, facies analysis, correlation techniques, and sequence and seismic stratigraphy. Application to hydrocarbon exploitation stressed throughout the course. Required of all PEGN students. Prerequisite: SYGN101, PEGN308, or consent of instructor. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN316. FIELD GEOLOGY (S) Six weeks of field work, stressing geology of the Southern Rocky Mountain Province. Measurement of stratigraphic sections. Mapping of igneous, metamorphic, and sedimentary terrain using air photos, topographic maps, plane table, and other methods. Diversified individual problems in petroleum geology, mining geology, engineering geology, structural geology, and stratigraphy. Formal reports submitted on several problems. Frequent evening lectures and discussion sessions. Field trips emphasize regional geology as well as mining, petroleum, and engineering projects. Prerequisite: GEGN 202, GEGN 206, GEOL314, GEOL309, and GEGN317. 6 semester hours (Field Term).

GEGN317. GEOLOGIC FIELD METHODS (II) Methods and techniques of geologic field observations and interpretations. Lectures in field techniques and local geology. Laboratory and field project in diverse sedimentary, igneous, metamorphic, structural, and surficial terrains using aerial photographs, topographic maps and compass and pace methods. Geologic cross sections maps, and reports. Weekend exercises required. Prerequisite to GEGN316. Prerequisite: GEGN202, GEOL309 or GEOL308. Completion or concurrent enrollment in GEGN206 and GEOL314. 1 hour lecture, 8 hours field; 2 semester hours.

GEOL321. MINERALOGY AND MINERAL CHARACTERIZATION (I) Principles of mineralogy and mineral characterization. Crystallography of naturally occurring

materials. Principles of crystal chemistry. Interrelationships among mineral structure, external shape, chemical composition, and physical properties. Introduction to mineral stability. Laboratories emphasize analytical methods, including X-ray diffraction, scanning electron microscopy, and optical microscopy. Prerequisite: SYGN 101, CHGN 124, GEGN 206. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN340. COOPERATIVE EDUCATION (I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

GEGN342. ENGINEERING GEOMORPHOLOGY (I) Study of interrelationships between internal and external earth processes, geologic materials, time, and resulting landforms on the Earth's surface. Influences of geomorphic processes on design of natural resource exploration programs and siting and design of geotechnical and geohydrologic projects. Laboratory analysis of geomorphic and geologic features utilizing maps, photo interpretation and field observations. Prerequisite: SYGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN/GEOL398. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING (I, II) Special topics classes taught on a one-time basis. May include lecture, laboratory and field trip activities. Prerequisite: Approval of instructor and department head. Variable credit; 1 to 6 semester hours.

GEGN399. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY (I, II) Individual special studies, laboratory and/or field problems in geological engineering or engineering hydrogeology. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

GEOL399. INDEPENDENT STUDY IN GEOLOGY (I, II) Individual special studies, laboratory and/or field problems in geology. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 semester hours.

Senior Year

GEGN401. MINERAL DEPOSITS (I) Introductory presentation of magmatic, hydrothermal, and sedimentary metallic ore deposits. Chemical, petrologic, structural, and sedimentological processes that contribute to ore formation. Description of classic deposits representing individual deposit types. Review of exploration sequences. Laboratory consists of hand specimen study of host rock-ore mineral suites and mineral deposit evaluation problems. Prerequisite: GEGN316 and DCGN209. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN403. MINERAL EXPLORATION DESIGN (II) (WI) Exploration project design: commodity selection, target selection, genetic models, alternative exploration approaches and associated costs, exploration models, property acquisition, and preliminary economic evaluation. Lectures and laboratory exercises to simulate the entire exploration sequence from inception and planning through implementation to discovery, with initial ore reserve calculations and preliminary economic evaluation. Prerequisite: GEGN401. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN404. ORE MICROSCOPY/ FLUID INCLUSIONS (II) Identification of ore minerals using reflected light microscopy, micro-hardness, and reflectivity techniques. Petrographic analysis of ore textures and their significance. Guided research on the ore mineralogy and ore textures of classic ore deposits. Prerequisites: GEOL321, GEGN401, or consent of instructor. 6 hours lab; 3 semester hours.

GEGN405. MINERAL DEPOSITS (I) Physical and chemical characteristics and geologic and geographic setting of magmatic, hydrothermal, and sedimentary metallic mineral deposits from the aspects of genesis, exploration, and mining. For non-majors. Prerequisite: GEOL308 or concurrent enrollment. 2 hours lecture; 2 semester hours.

GEGN 432. GEOLOGICAL DATA MANAGEMENT (I) Techniques for managing and analyzing geological data, including statistical analysis procedures and computer programming. Topics addressed include elementary probability, populations and distributions, estimation, hypothesis testing, analysis of data sequences, mapping, sampling and sample representativity, linear regression, and overview of univariate and multivariate statistical methods. Practical experience with principles of software programming and statistical analysis for geological applications via supplied software and data sets from geological case histories. Prerequisites: Senior standing in Geological Engineering or permission of instructor. 1 hour lecture, 6 hours lab; 3 semester hours.

GEGN438. PETROLEUM GEOLOGY (I) Source rocks, reservoir rocks, types of traps, temperature and pressure conditions of the reservoir, theories of origin and accumulation of petroleum, geology of major petroleum fields and provinces of the world, and methods of exploration for petroleum. Term report required. Laboratory consists of study of well log analysis, stratigraphic correlation, production mapping, hydrodynamics and exploration exercises. Prerequisite: GEOL309 and GEOL314; GEGN316 or GPGN486 or PEGN316. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN/GPGN/PEGN439. MULTI-DISCIPLINARY PETROLEUM DESIGN (II) (WI) This is a multi-disciplinary design course that integrates fundamentals and design concepts in geological, geophysical, and petroleum engineering. Students work in integrated teams from each of the disciplines. Open-ended design problems are assigned including the development of a prospect in an exploration play and a detailed

engineering field study. Detailed reports are required for the prospect evaluation and engineering field study. Prerequisite: GE Majors: GEOL308 or GEOL309, GEGN438, GEGN316; PE majors: PEGN316, PEGN414, PEGN422, PEGN423, PEGN424 (or concurrent) GEOL308; GP Majors: GPGN302 and GPGN303. 2 hours lecture; 3 hours lab; 3 semester hours.

GEGN442. ADVANCED ENGINEERING GEOMORPHOLOGY (II) Application of quantitative geomorphic techniques to engineering problems. Map interpretation, photo interpretation, field observations, computer modeling, and GIS analysis methods. Topics include: coastal engineering, fluvial processes, river engineering, controlling water and wind erosion, permafrost engineering. Multi-week design projects and case studies. Prerequisite: GEGN342 and GEGN468, or graduate standing; GEGN475/575 recommended. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN466. GROUNDWATER ENGINEERING (I) Theory of groundwater occurrence and flow. Relation of groundwater to surface; potential distribution and flow; theory of aquifer tests; water chemistry, water quality, and contaminant transport. Laboratory sessions on water budgets, water chemistry, properties of porous media, solutions to hydraulic flow problems, analytical and digital models, and hydrogeologic interpretation. Prerequisite: mathematics through calculus and MACS315, GEOL309, GEOL315, and EGGN351, or consent of instructor. 3 hours lecture, 3 semester hours.

GEGN467. GROUNDWATER ENGINEERING (I) Theory of groundwater occurrence and flow. Relation of groundwater to surface water; potential distribution and flow; theory of aquifer tests; water chemistry, water quality, and contaminant transport. Laboratory sessions on water budgets, water chemistry, properties of porous media, solutions to hydraulic flow problems, analytical and digital models, and hydrogeologic interpretation. Prerequisite: mathematics through calculus and MACS315, GEOL309, GEOL314 or GEOL315, and EGGN351, or consent of instructor. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN468. ENGINEERING GEOLOGY AND GEOTECHNICS (I) Application of geology to evaluation of construction, mining, and environmental projects such as dams, waterways, tunnels, highways, bridges, buildings, mine design, and land-based waste disposal facilities. Design projects including field, laboratory, and computer analysis are an important part of the course. Prerequisite: MNGN321 and concurrent enrollment in EGGN361/EGGN363 or consent of instructor. 3 hours lecture, 3 hours lab, 4 semester hours.

GEGN469. ENGINEERING GEOLOGY DESIGN (II) (WI) This is a capstone design course that emphasizes realistic engineering geologic/geotechnics projects. Lecture time is used to introduce projects and discussions of methods and procedures for project work. Several major projects will be assigned and one to two field trips will be required. Students work as individual investigators and in teams. Final written

design reports and oral presentations are required. Prerequisite: GEGN468 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN470. GROUND-WATER ENGINEERING DESIGN (II) (WI) Application of the principles of hydrogeology and ground-water engineering to water supply, geotechnical, or water quality problems involving the design of well fields, drilling programs, and/or pump tests. Engineering reports, complete with specifications, analysis, and results, will be required. Prerequisite: GEGN467 or equivalent or consent of instructor. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL470/GPGN470. APPLICATIONS OF SATELLITE REMOTE SENSING (II) Students are introduced to geoscience applications of satellite remote sensing. Introductory lectures provide background on satellites, sensors, methodology, and diverse applications. One or more areas of application are presented from a systems perspective. Guest lecturers from academia, industry, and government agencies present case studies focusing on applications, which vary from semester to semester. Students do independent term projects, under the supervision of a faculty member or guest lecturer, that are presented both written and orally at the end of the term. Prerequisites: consent of instructor. 3 hours lecture; 3 semester hours.

GEGN473. GEOLOGICAL ENGINEERING SITE INVESTIGATION (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.

GEGN475. APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS (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 projects, as well as video presentations. Prerequisite: SYGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN476. DESKTOP MAPPING APPLICATIONS FOR PROJECT DATA MANAGEMENT (I, II) Conceptual overview and hands-on experience with a commercial desktop mapping system. Display, analysis, and presentation mapping functions; familiarity with the software components, including graphical user interface (GUI); methods for handling different kinds of information; organization and storage of project documents. Use of raster and vector data in an integrated environment; basic raster concepts; introduction to

GIS models, such as hill shading and cost/distance analysis. Prerequisite: No previous knowledge of desktop mapping or GIS technology assumed. Some computer experience in operating within a Windows environment recommended. 1 hour lecture; 1 semester hour

GEGN481. ADVANCED HYDROGEOLOGY (I) Lectures, assigned readings, and discussions concerning the theory, measurement, and estimation of ground water parameters, fractured-rock flow, new or specialized methods of well hydraulics and pump tests, tracer methods, and well construction design. Design of well tests in variety of settings. Prerequisites: GEGN467 or consent of instructor. 3 hours lecture; 3 semester hours.

GEGN483. MATHEMATICAL MODELING OF GROUND-WATER SYSTEMS (II) Lectures, assigned readings, and direct computer experience concerning the fundamentals and applications of analytical and finite-difference solutions to ground water flow problems as well as an introduction to inverse modeling. Design of computer models to solve ground water problems. Prerequisites: Familiarity with computers, mathematics through differential and integral calculus, and GEGN467. 3 hours lecture; 3 semester hours.

GEGN/GEOL498. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING (I, II) Special topics classes taught on a one-time basis. May include lecture, laboratory and field trip activities. Prerequisite: Approval of instructor and department head. Variable credit; 1 to 6 semester hours.

GEGN499. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY (I, II) Individual special studies, laboratory and/or field problems in geological engineering or engineering hydrogeology. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

GEOL499. INDEPENDENT STUDY IN GEOLOGY (I, II) Individual special studies, laboratory and/or field problems in geology. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Oceanography

GEOC407. ATMOSPHERE, WEATHER AND CLIMATE (II)

An introduction to the Earth's atmosphere and its role in weather patterns and long term climate. Provides basic understanding of origin and evolution of the atmosphere, Earth's heat budget, global atmospheric circulation and modern climatic zones. Long- and short-term climate change including paleoclimatology, the causes of glacial periods and global warming, and the depletion of the ozone layer. Causes and effects of volcanic eruptions on climate, El Nino, acid rain, severe thunderstorms, tornadoes, hurricanes, and avalanches are also discussed. Microclimates and weather patterns common in Colorado. Prerequisite: Completion of CSM freshman technical core, or equivalent. 3 hours lecture; 3 semester hours. Offered alternate years; Spring 2005.

GEOC408. INTRODUCTION TO OCEANOGRAPHY (II)

An introduction to the scientific study of the oceans, including chemistry, physics, geology, biology, geophysics, and mineral resources of the marine environment. Lectures from pertinent disciplines are included. Recommended background: basic college courses in chemistry, geology, mathematics, and physics. 3 hours lecture; 3 semester hours. Offered alternate years; Spring 2004.

Geophysics

TERENCE K. YOUNG, Professor and Department Head

THOMAS L. DAVIS, Professor

DAVE HALE, Charles Henry Green Professor of Exploration
Geophysics

GARY R. OLHOEFT, Professor

MAX PEETERS, Baker Hughes Professor of Petrophysics and
Borehole Geophysics

ROEL K. SNIEDER, Keck Foundation Professor of Basic
Exploration Science

ILYA D. TSVANKIN, Professor

THOMAS M. BOYD, Associate Professor and Dean of Graduate
Studies

YAOGUO LI, Associate Professor

LIZET B. CHRISTIANSEN, Assistant Professor

PAUL C. SAVA, Assistant Professor

NORMAN BLEISTEIN, Research Professor and University
Emeritus Professor

KENNETH L. LARNER, Research Professor and University
Emeritus Professor

MICHAEL L. BATZLE, Research Associate Professor

ROBERT D. BENSON, Research Associate Professor

MANIKA PRASAD, Research Associate Professor

FENG SU, Research Associate Professor

STEPHEN J. HILL, Adjunct Associate Professor

DAVID J. WALD, Adjunct Associate Professor

WARREN B. HAMILTON, Distinguished Senior Scientist

PIETER HOEKSTRA, Distinguished Senior Scientist

THOMAS R. LAFEHR, Distinguished Senior Scientist

MISAC N. NABIGHIAN, Distinguished Senior Scientist

ADEL ZOHDY, Distinguished Senior Scientist

FRANK A. HADSELL, Emeritus Professor

ALEXANDER A. KAUFMAN, Emeritus Professor

GEORGE V. KELLER, Emeritus Professor

PHILLIP R. ROMIG, JR., Emeritus Professor

Program Description

Geophysicists study the Earth's interior through physical measurements collected at the earth's surface, in boreholes, from aircraft, or from satellites. Using a combination of mathematics, physics, geology, chemistry, hydrology, and computer science, both geophysicists and geophysical engineers analyze these measurements to infer properties and processes within the Earth's complex interior. Non-invasive imaging beneath the surface of Earth and other planets by geophysicists is analogous to non-invasive 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. 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 non-invasively the aging infrastructures 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 about 20% choosing to pursue graduate studies.

Founded in 1926, the Department of Geophysics at the Colorado School of Mines is recognized and respected around the world for its programs in applied geophysical research and education. With 20 active faculty and an average class size of 15, students receive individualized attention in a close-knit department. The Colorado School of Mines offers one of only two undergraduate geophysical engineering programs in the entire United States accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700. Geophysical Engineering undergraduates who may have an interest in professional registration as engineers are encouraged to take the Engineer in Training (EIT) / Fundamentals of Engineering (FE) exam as seniors. Given the interdisciplinary nature of geophysics, the undergraduate curriculum requires students to become thoroughly familiar with geological, mathematical, and physical theories in addition to the various geophysical methodologies.

Geophysics Field Camp. Each summer, a base of field operations is set up for four weeks in the mountains of Colorado for students who have completed their junior year. Students prepare geological maps and cross sections and then use these as the basis for conducting seismic, gravimetric, magnetic, and electrical surveys. After acquiring these various geophysical datasets, the students process the data and develop an interpretation that is consistent with all the information. In addition to the required four-week program, students can also participate in other diverse field experiences. In recent years these have included cruises on seismic ships in the Gulf of Mexico, studies at an archeological site, inves-

tigations at an environmental site, a ground-penetrating radar survey on an active volcano in Hawaii, and a well-logging school offered by Baker Atlas.

Study Abroad. The Department of Geophysics encourages its undergraduates to spend one or two semesters studying abroad. At some universities credits can be earned that substitute for course requirements in the geophysical engineering program at CSM. Information on universities that have established formal exchange programs with CSM can be obtained either from the Department of Geophysics or the Office of International Programs.

Combined BS/MS Program. Undergraduate students in the Geophysical Engineering program who would like to continue directly into the Master of Science program in Geophysics or Geophysical Engineering are allowed 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. Students interested to take advantage of this option should meet with their advisor or department head as early as possible in their undergraduate program to determine which elective courses will be acceptable and advantageous for accelerating them through their combined BS/MS studies.

Summer Jobs in Geophysics. In addition to the summer field camp experience, students are given opportunities every summer throughout their undergraduate career to work as summer interns within the industry, at CSM, or for government agencies. Students have recently worked outdoors with geophysics crews in various parts of the U.S., South America, and offshore in the Gulf of Mexico.

The Cecil H. and Ida Green Graduate and Professional Center. The lecture rooms, laboratories, and computer-aided instruction areas of the Department of Geophysics are located in the Green Center. The department maintains equipment for conducting geophysical field measurements, including magnetometers, gravity meters, ground-penetrating radar, and instruments for recording seismic waves. Students have access to the Department petrophysics laboratory for measuring properties of porous rocks. Undergraduate students also have their own room which is equipped with networked PCs and provides a friendly environment for work, study, relaxation, and socializing.

Geophysical Engineering Program Outcomes (Bachelor of Science in Geophysical Engineering)

Geophysical engineers and geophysicists must apply quantitative techniques to analyze an entity as complex as the Earth. Geophysical graduates, therefore, require a special combination of traits and abilities to thrive in this discipline. In addition to contributing toward achieving the educational outcomes described in the CSM Graduate Profile and the ABET Accreditation Criteria, the Geophysical Engineering Program at CSM strives to graduate students who:

1. Think for themselves and demonstrate the willingness to question conventional formulations of problems, and are capable of solving these problems independently.
2. Are creative and demonstrate the ability to conceive and validate new hypotheses, new problem descriptions, and new methods for analyzing data.
3. Are good experimentalists and have demonstrated the ability to design and carry out a geophysical field survey or laboratory experiment and ensure that the recorded data are of the highest-possible quality.
4. Can program a computer in a high-level language to acquire, process, model and display scientific data.
5. Can deal rationally with uncertainty and have demonstrated that they understand that geophysical data are always incomplete and uncertain; can quantify the uncertainty and recognize when it is not acceptable to make decisions based on these data.
6. Have demonstrated qualities that are the foundation of leadership; know the importance of taking risks, and are able to make good judgments about the level of risk that is commensurate with their knowledge, experience, and chance of failure; realize that failure is unavoidable if you want to learn and grow.

Curriculum

Geophysics is an applied and interdisciplinary science, hence students must have a strong foundation in physics, mathematics, geology and computer sciences. Superimposed on this foundation is a comprehensive body of courses on the theory and practice of geophysical methods. As geophysics and geophysical engineering involve the study and exploration of the entire earth, our graduates have great opportunities to work anywhere on, and even off, the planet. Therefore, emphasis is placed on electives in the humanities that give students an understanding of international issues and different cultures. To satisfy all these requirements, every student who obtains a Bachelor's Degree in Geophysical Engineering at CSM must complete the courses in the CSM Core Curriculum plus the following (see the course flowchart on the Department of Geophysics webpage):

Degree Requirements (Geophysical Engineering)

Sophomore Year Fall Semester	lec.	lab.	sem.hrs.
EBGN201 Principles of Economics	3		3
MACS213 Calculus for Scientists & Engineers III	4		4
①EPIC251 Design II Earth Engineering	3		3
PAGN201 Physical Education	2		0.5
PHGN200 Physics II	3.5	3	4.5
GEGN202 Geological Principles & Processes	3	3	4
Total			19

	lec.	lab.	sem.hrs.
Sophomore Year Spring Semester			
⁽¹⁾ MACS261 Programming Concepts Java	2	3	3
GPGN210 Materials of the Earth	3	3	4
GEOL308 Introductory Applied Structural Geology	2	3	3
MACS315 Differential Equations	3		3
PAGN202 Physical Education	2		0.5
SYGN200 Human Systems	3		3
Total			16.5
Junior Year Fall Semester			
GPGN303 Introduction to Gravity and Magnetic Methods	3	3	4
PHGN311 Introduction to Mathematical Physics	3		3
GPGN320 Continuum Mechanics	3		3
GPGN321 Theory of Fields I: Static Fields	3		3
GPGN315 Field Methods for Geophysicists		6	2
⁽²⁾ Electives	3		3
Total			18
Junior Year Spring Semester			
GEOL314 Stratigraphy	3	3	4
GPGN302 Introduction to Seismic Methods	3	3	4
GPGN308 Introduction to Electrical and Electromagnetic Methods	3	3	4
GPGN322 Theory of Fields II: Time Varying Fields	3		3
⁽²⁾ Electives	3		3
Total			18
Summer Session			
GPGN486 Geophysics Field Camp	4		4
Total			4
Senior Year Fall Semester			
GPGN404 Digital Systems Analysis	3		3
⁽³⁾ Advanced Elective	3		3
⁽⁴⁾ GPGN438 Senior Design or GPGN439 in Spring Semester			
⁽²⁾ Electives	6		6
Total			12
Senior Year Spring Semester			
GPGN432 Formation Evaluation	3	3	4
GPGN494 Physics of the Earth	3		3
⁽⁴⁾ GPGN439 Multi-disciplinary Petro. Design or GPGN438 beginning Fall Semester	2	3	3
GPGN470 Applications of remote sensing	3		3
⁽²⁾ Electives	6		6
Total			19
Grand Total			139.5

⁽¹⁾In Fall semester, sophomores should take the section of EPIC251 offered by the Department of Geophysics that introduces scientific computing. In Spring semester, sophomores take a course in object-oriented programming using Java.

⁽²⁾Electives must include at least 9 hours in an approved HSS Cluster. The Department of Geophysics encourages its students to consider organizing their electives to form a Minor or an Area of Special Interest (ASI). A guide suggesting various Minor and ASI programs can be obtained from the Department office.

⁽³⁾The advanced electives should be chosen from advanced GP methods courses (GPGN414, GPGN422, GPGN452) or technical courses

at 300 level and above from engineering and science departments at CSM and other universities. Courses from CSM are approved by the student's advisor; courses from other universities are approved by the Undergraduate Advisory Committee (UAC) of the Department of Geophysics.

⁽⁴⁾Students can take either GPGN438 or GPGN439 to satisfy the senior design requirement. The multidisciplinary design course GPGN439, offered only in Spring semester, is strongly recommended for students interested in petroleum exploration and production. Students interested in non-petroleum applications of geophysics take GPGN438 for 3 credit hours, either by enrolling for all 3 credit hours in one semester (Fall or Spring) or by enrolling for a portion of the 3 hours in Fall and the remainder in Spring.

Minor in Geophysics/Geophysical Engineering

Geophysics plays an important role in many aspects of civil engineering, petroleum engineering, mechanical engineering, and mining engineering, as well as mathematics, physics, geology, chemistry, hydrology, and computer science. Given the natural connections between these various fields and geophysics, it may be of interest for students in other majors to consider choosing to minor in geophysics, or to choose geophysics as an area of specialization. The core of courses taken to satisfy the minor requirement must include some of the following geophysics methods courses.

GPGN210, Materials of the Earth
 GPGN302, Seismic Methods
 GPGN303, Gravity and Magnetic Methods
 GPGN308, Electrical and Electromagnetic Methods
 GPGN419, Well Log Analysis and Formation Evaluation
 GPGN470, Applications of Satellite Remote Sensing

The remaining hours can be satisfied by a combination of other geophysics courses, as well as courses in geology, mathematics, and computer science depending on the student's major.

Students should consult with the Department of Geophysics to get their sequence of courses approved before embarking on a minor program.

Description of Courses

Freshman/Sophomore Year

GPGN198. SPECIAL TOPICS IN GEOPHYSICS (I, II)
 New topics in geophysics. Each member of the academic faculty is invited to submit a prospectus of the course to the department head for evaluation as a special topics course. If selected, the course can be taught only once under the 198 title before becoming part of the regular curriculum under a new course number and title. Prerequisite: Consent of department. Credit – variable, 1 to 6 hours.

GPGN199. GEOPHYSICAL INVESTIGATION (I, II)
 Individual project; instrument design, data interpretation, problem analysis, or field survey. Prerequisites: Consent of department and "Independent Study" form must be completed and submitted to the Registrar. Credit dependent upon nature and extent of project, not to exceed 6 semester hours.

GPGN210. MATERIALS OF THE EARTH (II) (WI) Introduction to the physical and chemical properties and processes in naturally occurring materials. Combination of elements to become gases, liquids and solids (minerals), and aggregation of fluids and minerals to become rocks and soils. Basic material properties that describe the occurrence of matter such as crystal structure, density, and porosity. Properties relating to simple processes of storage and transport through the diffusion equation (such as Fick, Ohm's, Hooke's, Fourier's, and Darcy's Laws) as exhibited in electric, magnetic, elastic, mechanical, thermal, and fluid flow properties. Coupled processes (osmosis, electromagnetic, nuclear magnetic relaxation). The necessity to statistically describe properties of rocks and soils. Multiphase mixing theories, methods of modeling and predicting properties. Inferring past processes acting on rocks from records left in material properties. Environmental influences from temperature, pressure, time and chemistry. Consequences of nonlinearity, anisotropy, heterogeneity and scale. Prerequisites: PHGN200 and MACS112, or consent of instructor. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN298. SPECIAL TOPICS IN GEOPHYSICS (I, II) New topics in geophysics. Each member of the academic faculty is invited to submit a prospectus of the course to the department head for evaluation as a special topics course. If selected, the course can be taught only once under the 298 title before becoming a part of the regular curriculum under a new course number and title. Prerequisite: Consent of department. Credit - variable, 1 to 6 hours.

GPGN299 GEOPHYSICAL INVESTIGATION (I, II) Individual project; instrument design, data interpretation, problem analysis, or field survey. Prerequisites: Consent of department and "Independent Study" form must be completed and submitted to the Registrar. Credit dependent upon nature and extent of project, not to exceed 6 semester hours.

Junior Year

GPGN302. SEISMIC METHODS I: INTRODUCTION TO SEISMIC METHODS (II) (WI) This is an introductory study of seismic methods for imaging the Earth's subsurface, with emphasis on reflection seismic exploration. Starting with the history and development of seismic exploration, the course proceeds through an overview of methods for acquisition of seismic data in land, marine, and transitional environments. Underlying theoretical concepts, including working initially with traveltimes equations for simple subsurface geometries, are used to introduce general issues in seismic data processing, as well as the nature of seismic data interpretation. The course introduces basic concepts, mathematics, and physics of seismic wave propagation (including derivation of the one-dimensional acoustic wave equation and its solution in multi-layered media), emphasizing similarities with the equations and physics that underlie all geophysical methods. Using analysis of seismometry as a first example

of linear time-invariant systems, the course brings Fourier theory and filter theory to life through demonstrations of their immense power in large-scale processing of seismic data to improve signal-to-noise ratio and ultimately the accuracy of seismic images of the Earth's subsurface. Prerequisites: PHGN200, MACS213, MACS315, and GPGN210, PHGN311, or consent of instructor. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN303. GRAVITY AND MAGNETIC METHODS (I) Introduction to land, airborne, oceanographic, and borehole gravity and magnetic exploration. Reduction of observed gravity and magnetic values. Theory of potential-field anomalies introduced by geologic distributions. Methods and limitations of interpretations. Prerequisites: PHGN200, MACS213, MACS315, and GPGN210, and concurrent enrollment in PHGN311, or consent of instructor. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN308. INTRODUCTION TO ELECTRICAL AND ELECTROMAGNETIC METHODS (II) This is an introductory course on electrical and electromagnetic methods for subsurface exploration. The course begins with a review of the factors influencing the electrical properties of rocks. Methods to be discussed are electrical methods with various electrode arrays for profiling and soundings, and ground and airborne electromagnetic methods using both natural (e.g. the magnetotelluric method) and man-made (e.g. the time domain method) sources for electromagnetic fields. Other techniques reviewed are self-potential, induced polarization and ground penetrating radar. The discussion of each method includes a treatise of the principles, instrumentation, procedures of data acquisition, analysis, and interpretation. These various methods are employed in geotechnical and environmental engineering and resources exploration (base and precious metals, industrial minerals, geothermal and hydrocarbons). The laboratory will focus on demonstrating various methods in the field, and working through case histories. Prerequisites: PHGN200, MACS213, MACS315, GPGN210, PHGN311, and GPGN321, or consent of instructor. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN311. SURVEY OF EXPLORATION GEOPHYSICS (I) The fundamentals of geophysical exploration are taught through the use of a series of computer simulations and field exercises. Students explore the physics underlying each geophysical method, design geophysical surveys, prepare and submit formal bids to clients contracting the work, and collect, process, and interpret the resulting data. Emphasis is placed on understanding the processes used in designing and interpreting the results of geophysical exploration surveys. Prior exposure to computer applications such as web browsers, spreadsheets, and word processors is helpful. Prerequisites: MACS213, PHGN200, and SYGN101. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN315. SUPPORTING GEOPHYSICAL FIELD INVESTIGATIONS (I) Prior to conducting a geophysical investigation, geophysicists often need input from related specialists such as geologists, surveyors, and land-men. Students are introduced to the issues that each of these specialists must address so that they may understand how each affects the design and outcome of geophysical investigations. Students learn to use and understand the range of applicability of a variety of surveying methods, learn the tools and techniques used in geological field mapping and interpretation, and explore the logistical and permitting issues directly related to geophysical field investigations. Prerequisite: GEOL308 or GEOL309, or consent of instructor. 6 hours lab, 2 semester hours.

GPGN320. ELEMENTS OF CONTINUUM MECHANICS AND WAVE PROPAGATION (I) Introduction to continuum mechanics and elastic wave propagation with an emphasis on principles and results important in seismology and earth sciences in general. Topics include a brief overview of elementary mechanics, stress and strain, Hooke's law, notions of geostatic pressure and isostasy, fluid flow and Navier-stokes equation. Basic discussion of the wave equation for elastic media, plane wave and their reflection/transmission at interfaces. Prerequisites: MACS213, PHGN200. 3 hours lecture; 3 semester hours.

GPGN321. THEORY OF FIELDS I: STATIC FIELDS (I) Introduction to the theory of gravitational, magnetic, and electrical fields encountered in geophysics. Emphasis on the mathematical and physical foundations of the various phenomena and the similarities and differences in the various field properties. Physical laws governing the behavior of the gravitational, electric, and magnetic fields. Systems of equations of these fields. Boundary value problems. Uniqueness theorem. Influence of a medium on field behavior. Prerequisites: PHGN200, MACS213, and MACS315, and concurrent enrollment in PHGN311 or consent of instructor. 3 hours lecture; 3 semester hours.

GPGN322. THEORY OF FIELDS II: TIME-VARYING FIELDS (II) Constant electric field. Coulomb's law. System of equations of the constant electric field. Stationary electric field and the direct current in a conducting medium. Ohm's law. Principle of charge conservation. Sources of electric field in a conducting medium. Electromotive force. Resistance. System of equations of the stationary electric field. The magnetic field, caused by constant currents. Biot-Savart law. The electromagnetic induction. Faraday's law. Prerequisite: GPGN321, or consent of instructor. 3 hours lecture; 3 semester hours.

GPGN340. COOPERATIVE EDUCATION (I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second se-

mester sophomore status and a cumulative grade-point average of 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

GPGN398. SPECIAL TOPICS IN GEOPHYSICS (I, II) New topics in geophysics. Each member of the academic faculty is invited to submit a prospectus of the course to the department head for evaluation as a special topics course. If selected, the course can be taught only once under the 398 title before becoming a part of the regular curriculum under a new course number and title. Prerequisite: Consent of department. Credit-variable, 1 to 6 hours.

GPGN399. GEOPHYSICAL INVESTIGATION (I, II) Individual project; instrument design, data interpretation, problem analysis, or field survey. Prerequisites: Consent of department and "Independent Study" form must be completed and submitted to the Registrar. Credit dependent upon nature and extent of project, not to exceed 6 semester hours.

Senior Year

GPGN404. DIGITAL SIGNAL ANALYSIS (I) The fundamentals of one-dimensional digital signal processing as applied to geophysical investigations are studied. Students explore the mathematical background and practical consequences of the sampling theorem, convolution, deconvolution, the Z and Fourier transforms, windows, and filters. Emphasis is placed on applying the knowledge gained in lecture to exploring practical signal processing issues. This is done through homework and in-class practicum assignments requiring the programming and testing of algorithms discussed in lecture. Prerequisites: MACS213, MACS315, and PHGN311, or consent of instructor. Knowledge of a computer programming language is assumed. 2 hours lecture; 2 hours lab, 3 semester hours.

GPGN414. ADVANCED GRAVITY AND MAGNETIC METHODS (II) Instrumentation for land surface, borehole, sea floor, sea surface, and airborne operations. Reduction of observed gravity and magnetic values. Theory of potential field effects of geologic distributions. Methods and limitations of interpretation. Prerequisite: GPGN303, or consent of instructor. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN419/PEGN419. WELL LOG ANALYSIS AND FORMATION EVALUATION (I) The basics of core analysis and the principles of all common borehole instruments are reviewed. The course shows (computer) interpretation methods that combine the measurements of various borehole instruments to determine rock properties such as porosity, permeability, hydrocarbon saturation, water salinity, ore grade, ash content, mechanical strength, and acoustic velocity. The impact of these parameters on reserves estimates of hydrocarbon reservoirs and mineral accumulations are demonstrated. In spring semesters, vertical seismic profiling, single well and cross-well seismic are reviewed. In the fall semester, top-

ics like formation testing, and cased hole logging are covered. Prerequisites: MACS315, PHGN311, GPGN302, GPGN303, GPGN308. 3 hours lecture, 2 hours lab; 3 semester hours.

GPGN422. ADVANCED ELECTRICAL AND ELECTROMAGNETIC METHODS (I) In-depth study of the application of electrical and electromagnetic methods to crustal studies, minerals exploration, oil and gas exploration, and groundwater. Laboratory work with scale and mathematical models coupled with field work over areas of known geology. Prerequisite: GPGN308, or consent of instructor. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN432. FORMATION EVALUATION (II) The basics of core analysis and the principles of all common borehole instruments are reviewed. The course teaches interpretation methods that combine the measurements of various borehole instruments to determine rock properties such as porosity, permeability, hydrocarbon saturation, water salinity, ore grade and ash content. The impact of these parameters on reserve estimates of hydrocarbon reservoirs and mineral accumulations is demonstrated. Geophysical topics such as vertical seismic profiling, single well and cross-well seismic are emphasized in this course, while formation testing, and cased hole logging are covered in GPGN419/PEGN419 presented in the fall. The laboratory provides on-line course material and hands-on computer log evaluation exercises. Prerequisites: MACS315, PHGN311, GPGN302, GPGN303 and GPGN308. 3 hours lecture, 3 hours lab; 4 semester hours. Only one of the two courses GPGN432 and GPGN419/PEGN419 can be taken for credit.

GPGN438. GEOPHYSICS PROJECT DESIGN (I, II) (WI) Complementary design course for geophysics restricted elective course(s). Application of engineering design principles to geophysics through advanced work, individual in character, leading to an engineering report or senior thesis and oral presentation thereof. Choice of design project is to be arranged between student and individual faculty member who will serve as an advisor, subject to department head approval. Prerequisites: GPGN302, GPGN303, GPGN308, and completion of or concurrent enrollment in geophysics method courses in the general topic area of the project design. Credit variable, 1 to 3 hours. Course can be retaken once.

GPGN439. GEOPHYSICS PROJECT DESIGN (II) GEGN439/PEGN439. MULTI-DISCIPLINARY PETROLEUM DESIGN (II) This is a multidisciplinary design course that integrates fundamentals and design concepts in geological, geophysical, and petroleum engineering. Students work in integrated teams consisting of students from each of the disciplines. Multiple open-end design problems in oil and gas exploration and field development, including the development of a prospect in an exploration play and a detailed engineering field study, are assigned. Several detailed written and oral presentations are made throughout the semester.

Project economics including risk analysis are an integral part of the course. Prerequisites: GP majors: GPGN302 and GPGN303. GE Majors: GEOL308 or GEOL309, GEGN316, GEGN438. PE majors: PEGN316, PEGN414, PEGN422, PEGN423, PEGN424 (or concurrent). 2 hours lecture, 3 hours lab; 3 semester hours.

GPGN452. ADVANCED SEISMIC METHODS (I) Historical survey. Propagation of body and surface waves in elastic media; transmission and reflection at single and multiple interfaces; energy relationships; attenuation factors; data processing (including velocity interpretation, stacking, and migration); and interpretation techniques. Acquisition, processing, and interpretation of laboratory model data; seismic processing using an interactive workstation. Prerequisites: GPGN302 and concurrent enrollment in GPGN404, or consent of instructor. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN470/GEOL470. APPLICATIONS OF SATELLITE REMOTE SENSING (II) Students are introduced to geoscience applications of satellite remote sensing. Introductory lectures provide background on satellites, sensors, methodology, and diverse applications. One or more areas of application are presented from a systems perspective. Guest lecturers from academia, industry, and government agencies present case studies focusing on applications, which vary from semester to semester. Students do independent term projects, under the supervision of a faculty member or guest lecturer, that are presented both written and orally at the end of the term. Prerequisites: PHGN200, MACS315, GEOL308 or GEOL309, or consent of instructor. 3 hours lecture; 3 semester hours.

GPGN486. GEOPHYSICS FIELD CAMP (S) Introduction to geological and geophysical field methods. The program includes exercises in geological surveying, stratigraphic section measurements, geological mapping, and interpretation of geological observations. Students conduct geophysical surveys related to the acquisition of seismic, gravity, magnetic, and electrical observations. Students participate in designing the appropriate geophysical surveys, acquiring the observations, reducing the observations, and interpreting these observations in the context of the geological model defined from the geological surveys. Prerequisites: GEOL308 or GEOL309, GEOL314, GPGN302, GPGN303, GPGN308, GPGN315 or consent of instructor. Up to 6 weeks field; up to 6 semester hours, minimum 4 hours

GPGN494. PHYSICS OF THE EARTH (II) (WI) Students will explore the fundamental observations from which physical and mathematical inferences can be made regarding the Earth's origin, structure, and evolution. These observations include traditional geophysical observations (e.g., seismic, gravity, magnetic, and radioactive) in addition to geochemical, nucleonic, and extraterrestrial observations. Emphasis is placed on not only cataloging the available data sets, but on

developing and testing quantitative models to describe these disparate data sets. Prerequisites: GEGN202, GPGN302, GPGN303, GPGN308, PHGN311, and MACS315, or consent of instructor. 3 hours lecture; 3 semester hours.

GPGN498. SPECIAL TOPICS IN GEOPHYSICS (I, II)

New topics in geophysics. Each member of the academic faculty is invited to submit a prospectus of the course to the department head for evaluation as a special topics course. If selected, the course can be taught only once under the 498 title before becoming a part of the regular curriculum under a new course number and title. Prerequisite: Consent of department. Credit-variable, 1 to 6 hours.

GPGN499. GEOPHYSICAL INVESTIGATION (I, II) Individual project; instrument design, data interpretation, problem analysis, or field survey. Prerequisite: Consent of department, and “Independent Study” form must be completed and submitted to the Registrar. Credit dependent upon nature and extent of project, not to exceed 6 semester hours.

Liberal Arts and International Studies

LAURA J. PANG, Associate Professor and Division Director
CARL MITCHAM, Professor
BARBARA M. OLDS, Professor and Associate Vice President for Educational Innovation
EUL-SOO PANG, Professor
ARTHUR B. SACKS, Professor and Associate Vice President for Academic & Faculty Affairs
HUSSEIN A. AMERY, Associate Professor
JAMES V. JESUDASON, Associate Professor
JUAN C. LUCENA, Associate Professor
SYLVIA GAYLORD, Assistant Professor
TINA L. GIANQUITTO, Assistant Professor
JOHN R. HEILBRUNN, Assistant Professor
JON LEYDENS, Assistant Professor and Writing Program Administrator
SUZANNE M. MOON, Assistant Professor
JAMES D. STRAKER, Assistant Professor
SANDY WOODSON, Senior Lecturer and Undergraduate Advisor
ROBERT KLIMEK, Lecturer
TONI LEFTON, Lecturer
ROSE PASS, Lecturer
JENNIFER SCHNEIDER, Lecturer
SUSAN J. TYBURSKI, Lecturer
GEORGE WILLIAM SHERK, Associate Research Professor
BETTY J. CANNON, Emeritus Associate Professor
W. JOHN CIESLEWICZ, Emeritus Professor
DONALD I. DICKINSON, Emeritus Professor
WILTON ECKLEY, Emeritus Professor
PETER HARTLEY, Emeritus Associate Professor
T. GRAHAM HEREFORD, Emeritus Professor
JOHN A. HOGAN, Emeritus Professor
KATHLEEN H. OCHS, Emeritus Associate Professor
ANTON G. PEGIS, Emeritus Professor
THOMAS PHILIPOSE, University Emeritus Professor
JOSEPH D. SNEED, Emeritus Professor
RONALD V. WIEDENHOEFT, Emeritus Professor
KAREN B. WILEY, Emeritus Associate Professor
ROBERT E.D. WOOLSEY, Emeritus Professor

Program Description

The Division of Liberal Arts and International Studies (LAIS) does not offer an undergraduate degree. It does offer five minor programs (see below). LAIS also offers a Master of International Political Economy of Resources, Graduate Certificates in International Political Economy, and a Graduate Individual Minor. (see the Graduate Bulletin for details).

The LAIS curriculum is based in the many disciplines that comprise the Humanities and Social Sciences. Coursework in LAIS prepares students for the non-technical challenges of their future professional lives and brings intellectual enrichment to their personal lives. LAIS courses examine the cultural, philosophical, ethical, social, political, environmental, international, and global contexts, past and present, which impact the practice and application of science and engineering in today's world.

Two of three required core courses in the Humanities and Social Sciences are delivered by LAIS, namely LAIS 100 (previously LIHU 100), Nature and Human Values, and SYGN 200, Human Systems. The third required core course, EBGN 201, Principles of Economics, is delivered by the Division of Economics and Business. Students may choose to satisfy their economics requirement by taking *both* EBGN 311, Principles of Microeconomics, and EBGN 312, Principles of Macroeconomics, in lieu of EBGN 201.

Beyond the core, LAIS offers the majority of the courses that meet the 9 credit-hour Clusters requirement in the Humanities and Social Sciences, in partnership with the Division of Economics and Business. Students choose *one* of three thematic clusters within which to complete this requirement: the Humanities Cluster; the Public Policy Cluster; or the International Studies Cluster. All students, except single majors in Economics and Business, may apply both EBGN 311 and EBGN 312 toward completing the Public Policy Cluster.

The Division's faculty members strive for excellence in both their teaching and research and expect high levels of academic performance from their students. Disciplinary expertise within LAIS among its full-time faculty includes: Composition; Creative Writing; Culture Studies; Film and Media Studies; Geography; History; International Political Economy; Law (including environmental policy); Literature; Music; Philosophy (including Ethics); Political Science; Science and Technology Studies; Science, Technology, and Society Studies; and Sociology. Adjunct faculty members add expertise in Art, Foreign Languages, and Operations Research, and add depth in History, Law, Literature, and Political Science.

As a service to the CSM community, the LAIS Division operates the LAIS Writing Center, which provides students with instruction tailored to their individual writing problems, and faculty with support for Writing Across the Curriculum. Faculty and staff are also welcome to make use of the Writing Center's expertise for writing projects and problems.

Program Educational Objectives

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the course work in the Division of Liberal Arts and International Studies is designed to help CSM develop in students the ability to engage in life-long learning and recognize the value of doing so by acquiring the broad education necessary to:

- a) understand the impact of engineering solutions in contemporary, global, international, societal, political, and ethical contexts;
- b) understand the role of Humanities and Social Sciences in identifying, formulating, and solving engineering problems;
- c) prepare people to live and work in a complex world;

- d) understand the meaning and implications of “stewardship of the Earth”;
- e) to communicate effectively in writing and orally.

Curriculum

Key to courses offered by the LAIS Division:

LAIS	Humanities and Social Sciences
LICM	Communication
LIFL	Foreign Language
LIMU	Music
SYGN	Systems

CSM students in all majors must take 19 credit-hours in Humanities and Social Science courses ranging from freshman through senior levels of course work. These courses are housed in LAIS and the Division of Economics and Business (EB).

Ten of the 19 hours are specified: LAIS 100 (previously LIHU100), Nature and Human Values (4 credit-hours); SYGN200, Human Systems (3 credit-hours); and EBGN201, Principles of Economics (3 credit-hours). The remaining 9 credit-hours must be chosen from a thematic cluster area (see below.)

NOTE: Students may elect to satisfy the Economics core requirement by taking both EBGN311 and EBGN312 instead of EBGN201. Students (other than single majors in Economics) choosing the EBGN 311 and 312 option may apply both of these courses toward fulfilling the Public Policy cluster. Students considering a major in Economics are advised to take the EBGN311/312 sequence instead of taking EBGN201.

NOTE: Any LAIS course, including Communication and Music courses, may be taken as a free elective.

NOTE: See the Foreign Languages (LIFL) section below for the CSM foreign language policy relative to restrictions that apply to previous foreign language course work, or native or second language knowledge/fluency.

Required Courses

LAIS 100 (previously LIHU100)	Nature and Human Values	4 sem hrs.
EBGN201	Principles of Economics	3 sem hrs.
SYGN200	Human Systems	3 sem hrs.
LAIS/EBGN	Cluster Courses	9 sem hrs.
Total		19 sem hrs.

Cluster Requirements

1. Undergraduate students are required to take a minimum of 9 credit-hours from one of the following clusters: Humanities (formerly Humankind & Values); Public Policy (formerly Society & Decisions and Environment, Resources, Science, & Technology); or International Studies (no change). Students who began to fulfill their cluster requirements prior to the beginning of the academic year 2004-05 have the option of staying with the previous cluster structure (“Humankind and Values,” “Society and Decisions,” “Environment, Resources,

Science, and Technology,” and “International Studies”), or they may switch to the new structure (“Humanities,” “Public Policy,” or “International Studies”). Students who did not begin fulfilling their cluster requirements as of the beginning of the academic year 2004-05 must do so within the new structure.

2. Three of the 9 credit-hours must be a 400-level LAIS (previously LIHU or LISS) course, or a 400-level EBGN course with a policy focus as indicated in the Clusters lists.
3. Single majors in Economics must take all 9 credit-hours from LAIS.
4. Students other than single majors in Economics may take up to 6 credit-hours in EBGN.

HUMANITIES CLUSTER (formerly Humankind & Values)

EBGN401 History of Thought
 LIFLxxx All LIFL (foreign language) courses
 LAIS220 Introduction to Philosophy
 LAIS221 (previously LISS312) Introduction to Religion
 LAIS285 (previously LISS375) Introduction to Law & Legal Systems
 LAIS298 (previously LIHU or LISS298) Special Topics
 LAIS299 (previously LIHU or LISS299) Independent Study
 LAIS300 (previously LIHU301) Creative Writing: Fiction
 LAIS301 (previously LIHU305) Creative Writing: Poetry
 LAIS305 (previously LIHU376) American Literature: Colonial Period to the Present
 LAIS306 (previously LIHU377) African American Literature: Foundations to Present
 LAIS314 (previously LIHU300) Journey Motif in Modern Literature
 LAIS315 (previously LIHU339) Musical Traditions of the Western World
 LAIS317 (previously LISS455) Japanese History & Culture
 LAIS320 (previously LIHU325) Introduction to Ethics
 LAIS321 (previously LIHU326) Political Philosophy & Engineering
 LAIS322 Introduction to Logic
 LAIS325 (previously LISS300) Cultural Anthropology
 LAIS365 (previously LIHU350) History of War
 LAIS375 (previously LIHU362) Engineering Cultures
 LAIS379 (previously LISS410) Utopias/Dystopias
 LAIS398 (previously LIHU or LISS398) Special Topics
 LAIS399 (previously LIHU or LISS399) Independent Study
 LAIS401 (previously LIHU405) Creative Writing: Poetry
 LAIS402 (previously LIHU412) Writing Proposals for a Better World
 LAIS405 (previously LIHU470) Becoming American: Literary Perspectives
 LAIS406 (previously LIHU401) The American Dream: Illusion or Reality?
 LAIS409 (previously LIHU406) Shakespearean Drama
 LAIS414 (previously LIHU402) Heroes and Anti-Heroes
 LAIS420 (previously LIHU420) Business, Engineering Leadership Ethics
 LAIS465 (previously LIHU479) The American Military Experience
 LAIS470 (previously LISS461) Technology and Gender: Issues
 LAIS475 (previously LIHU363) Engineering Cultures in the Developing World
 LAIS476 (previously LIHU460) Technology & International Development

LAIS485 (previously LISS474) Constitutional Law and Politics
 LAIS486 (previously LISS462) Science & Technology Policy
 LAIS498 (previously LIHU or LISS498) Special Topics
 LAIS499 (previously LIHU or LISS499) Independent Study

PUBLIC POLICY CLUSTER (formerly Society & Decisions and Environment, Resources, Science, & Technology)

EBGN310 Environment & Resource Economics
 EBG311 Microeconomics
 EBG312 Macroeconomics
 EBG330 Energy Economics
 EBG342 Economic Development
 EBG401 History of Economic Thought
 EBG441 International Economics
 LAIS220 Introduction to Philosophy
 LAIS221 (previously LISS 312) Introduction to Religions
 LAIS285 (previously LISS375) Introduction to Law & Legal Systems
 LAIS298 (previously LIHU or LISS298) Special Topics
 LAIS299 (previously LIHU or LISS299) Independent Study
 LAIS320 (previously LIHU325) Introduction to Ethics
 LAIS335 (previously LISS340) IPE of Latin America
 LAIS337 (previously LISS342) IPE of Asia
 LAIS339 (previously LISS344) IPE of Middle East
 LAIS341 (previously LISS346) IPE of Africa
 LAIS345 (previously LISS335) International Political Economy (IPE)
 LAIS370 (previously LIHU365) History of Science
 LAIS371 (previously LIHU367) History of Technology
 LAIS398 (previously LIHU or LISS398) Special Topics
 LAIS399 (previously LIHU or LISS399) Independent Study
 LAIS402 (previously LIHU412) Writing Proposals for a Better World
 LAIS420 (previously LIHU420) Business, Engineering & Leadership Ethics
 LAIS470 (previously LISS461) Technology & Gender: Issues
 LAIS485 (previously LISS474) Constitutional Law & Politics
 LAIS486 (previously LISS462) Science & Technology Policy
 LAIS487 (previously LISS480) Environmental Politics and Policy
 LAIS488 (previously LISS482) Water Politics & Policy
 LAIS498 (previously LIHU or LISS498) Special Topics
 LAIS499 (previously LIHU or LISS499) Independent Study

INTERNATIONAL STUDIES CLUSTER

EBGN312 Principles of Macroeconomics
 EBG342 Economic Development
 EBG441 International Economics
 LIFLxxx All LIFL (foreign language) Courses
 LAIS298 (previously LIHU or LISS298) Special Topics
 LAIS299 (previously LIHU or LISS299) Independent Study
 LAIS317 (previously LISS455) Japanese History & Culture
 LAIS335 (previously LISS340) IPE of Latin America
 LAIS337 (previously LISS342) IPE of Asia
 LAIS339 (previously LISS344) IPE of the Middle East
 LAIS341 (previously LISS346) IPE of Africa
 LAIS345 (previously LISS335) International Political Economy (IPE)
 LAIS370 (previously LIHU365) History of Science
 LAIS371 (previously LIHU367) History of Technology
 LAIS375 (previously LIHU362) Engineering Cultures
 LAIS398 (previously LIHU or LISS398) Special Topics

LAIS399 (previously LIHU or LISS399) Independent Study
 LAIS435 (previously LISS440) Latin American Development
 LAIS436 (previously LISS441) Hemispheric Integration in the Americas
 LAIS437 (previously LISS442) Asian Development
 LAIS441 (previously LISS446) African Development
 LAIS442 (previously LISS447) Natural Resources & War in Africa
 LAIS446 (previously LISS430) Globalization
 LAIS447 (previously LISS433) Global Corporations
 LAIS448 (previously LISS431) Global Environmental Issues
 LAIS449 (previously LISS432) Cultural Dynamics of Global Development
 LAIS450 (previously LISS435) Political Risk Assessment
 LAIS451 (previously LISS439) Political Risk Assessment Research Seminar
 LAIS452 (Previously LISS437) Corruption and Development
 LAIS459 (previously LISS434) International Field Practicum
 LAIS475 (previously LIHU363) Engineering Cultures in the Developing World
 LAIS476 (previously LIHU460) Technology & International Development
 LAIS498 (previously LIHU or LISS498) Special Topics
 LAIS499 (previously LIHU or LISS499) Independent Study

Minor Programs

LAIS offers five minor programs. Students who elect to pursue a minor usually will automatically satisfy their Cluster requirements. They will also need to use their free elective hours to complete a minor. Students may choose to pursue an Area of Special Interest (ASI) in any of the LAIS minor programs. Minors are a minimum of 18 credit-hours; ASIs are a minimum of 12 credit-hours. No more than half the credits to be applied towards an LAIS minor or ASI may be transfer credits. The LAIS Undergraduate Advisor must approval all transfer credits that will be used for an LAIS minor or ASI.

Prior to the completion of the sophomore year, a student wishing to declare an LAIS Minor must fill out an LAIS Minor form (available in the LAIS Office) and obtain approval signatures from the appropriate minor advisor in LAIS and from the LAIS Director. The student must also fill out a Minor/Area of Special Interest Declaration (available in the Registrar's Office) and obtain approval signatures from the student's CSM advisor, from the Head or Director of the student's major department or division, and from the LAIS Director.

The five minors or ASIs available and their advisors are:

Humanities Minor.	Dr. Tina Gianquitto
International Political Economy Minor.	
	Dr. James Jesudason
Science, Technology, and Society Minor.	
	Dr. Carl Mitcham
Humanitarian Studies and Technology	
	Dr. Juan Lucena
Individualized Undergraduate Minor.	
	Prof. Sandy Woodson

Students should consult these advisors for the specific requirements for these minors.

Humanities Minor

Program Advisor: Dr. Tina Gianquitto. The focus in the Humanities is the memorial record of the human imagination and intellect, discovering, recreating, and critically examining the essential core of experience that sustains the human spirit in all adventures of our common life. The making of this record appears in various forms of art, including Literature, Visual Arts, Music (non-performing), Philosophy, and History. The Humanities (HU) Minor offers a variety of opportunities to explore the wealth of our heritage. Students work with the HU Advisor to design a coherent set of courses to constitute a minor program appropriate to their interests.

International Political Economy Minor

Program Advisor: Dr. James Jesudason. Ideal for students anticipating careers in the earth resources industries. The International Political Economy (IPE) Program at CSM was the first such program in the U.S. designed with the engineering and applied science student in mind, and remains one of the very few international engineering programs with this focus. International Political Economy is the study of the interplay among politics, the economy, and culture. In today's global economy, international engineering and applied science decisions are fundamentally political decisions made by sovereign nations. Therefore, International Political Economy theories and models are often used in evaluating and implementing engineering and science projects. Project evaluations and feasibilities now involve the application of such IPE methods as political risk assessment and mitigation.

The IPE Program at CSM includes courses focusing on Latin America/the Americas, Asia Pacific, Sub-Saharan Africa, and the Middle East/Islamic World; courses with a global focus; and foreign language study.

The IPE minor is also a gateway to the Combined Undergraduate/Graduate Program in International Political Economy. The Combined Program leads to either a master's degree (Master of International Political Economy of Resources), or either one or two Graduate Certificates (15 credit-hours each) in International Political Economy. See the Graduate Bulletin for further details.

Science, Technology, and Society Minor

Program Advisor: Dr. Carl Mitcham. The Science, Technology, and Society (STS) Minor focuses on science and technology (or technoscience) in a societal context: how technoscience influences society, and how society influences technosciences. Courses provide historical and analytical approaches to questions inevitably confronting professional scientists, engineers, managers, and policy makers in both public and private sectors. Such questions concern, for example, professional ethical responsibilities, intellectual property rights, science policy formation, appropriate regulatory regimes, assessments of societal impacts, and the roles

of technical innovation in economic development or international competitiveness. Students work with the STS Advisor to tailor a course sequence appropriate to their interests and background.

Humanitarian Studies and Technology Minor

Program Advisor: Dr. Juan Lucena. The Humanitarian Studies and Technology Minor (HST) concerns itself with the intersection of society, culture, and technology in humanitarian projects. Technologically-oriented humanitarian projects are intended to provide fundamental needs (like food, water, shelter, and clothing) when these are missing or inadequate, or higher-level needs for underserved communities. HST courses are offered through LAIS with additional technical electives offered by departments across campus. Students may also wish to investigate the 28-credit minor in Humanitarian Engineering.

Individualized Undergraduate Minor

Program Advisor: Prof. Sandy Woodson. Students declaring an Undergraduate Individual Minor in LAIS must choose 18 restricted elective hours in LAIS in accordance with a coherent rationale reflecting some explicit focus that the student wishes to pursue. A student desiring this minor must design it in consultation with a member of the LAIS faculty who approves the rationale and the choice of courses.

Description of Courses

IMPORTANT NOTICE: NEW COURSE NUMBERING SYSTEM.

Effective Fall 2005, the Division of Liberal Arts and International Studies completely renumbered its Humanities, Social Sciences, and Foreign Language courses. The previous designations of "LIHU" and "LISS" have been replaced by the common designation "LAIS." Foreign language courses continue to retain the designation "LIFL," but the course numbers themselves have changed to bring CSM in line with standard numbering practices at public institutions of higher education elsewhere in Colorado.

The courses listed below follow the new numerical sequence, which differs from the previous sequence in which LIHU and LISS courses appeared. The old numbers appear in parentheses after the new numbers. A conversion table for course number may be found in the CSM 2005-2006 Undergraduate Bulletin.

Please direct any questions or concerns to the Division of Liberal Arts and International Studies.

CLUSTER CODES

Each of the courses listed below that is a "cluster course" has a code that appears in parentheses after the title to indicate to which cluster or clusters the course applies.

Example 1: A course which counts toward only one cluster. "LAIS 301. CREATIVE WRITING: FICTION (H)," wherein "(H)" indicates that this course counts toward fulfilling requirements in the Humanities (H) cluster only.

Example 2: A course which counts toward two different clusters. "LAIS 345. International Political Economy (PI)," wherein "(PI)" indicates that this course counts toward fulfilling requirements in either the Public Policy (P) or International Studies (I) cluster.

Code

H	Humanities Cluster only
P	Public Policy Cluster only
I	International Studies Cluster only
HP	Humanities or Public Policy Cluster
HI	Humanities or International Studies Cluster
PI	Public Policy or International Studies Cluster

LAIS 100 (previously LIHU100). NATURE AND HUMAN VALUES (NHV) Nature and Human Values will focus on diverse views and critical questions concerning traditional and contemporary issues linking the quality of human life and Nature, and their interdependence. The course will examine various disciplinary and interdisciplinary approaches regarding two major questions: 1) How has Nature affected the quality of human life and the formulation of human values and ethics? (2) How have human actions, values, and ethics affected Nature? These issues will use cases and examples taken from across time and cultures. Themes will include but are not limited to population, natural resources, stewardship of the Earth, and the future of human society. This is a writing-intensive course that will provide instruction and practice in expository writing, using the disciplines and perspectives of the Humanities and Social Sciences. 4 hours lecture/seminar; 4 semester hours.

LAIS 101 (previously LIHU 101) SHORT FORM NATURE AND HUMAN VALUES For students with a minimum of three strong composition and related transfer credits, this course will, with LAIS undergraduate advisory permission, complete the LAIS 100 (LIHU 100) Nature and Human and Value requirement. Prerequisite: transfer college composition course. 2 hours lecture/discussion; 2 semester hours.

LAIS 198 (previously LIHU198). SPECIAL TOPICS Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit: 1 to 6 semester hours.

LAIS 199 (previously LIHU 199) INDEPENDENT STUDY Individual research or special problem projects supervised by a faculty member. Primarily for students who have completed their Humanities and Social Science requirements. Instructor consent required. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit: 1 to 6 semester hours.

LAIS 220 INTRODUCTION TO PHILOSOPHY A general introduction to philosophy that explores historical and analytic traditions. Historical exploration may compare and contrast ancient and modern, rationalist and empiricist, European and Asian approaches to philosophy. Analytic exploration may consider such basic problems as the distinction between

illusion and reality, the one and the many, the structure of knowledge, the existence of God, the nature of mind or self. 3 hours lecture, 3 credit hours. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200.

LAIS 221 (previously LISS 312). INTRODUCTION TO RELIGIONS (HP) This course has two focuses. We will look at selected religions emphasizing their popular, institutional, and contemplative forms; these will be four or five of the most common religions: Hinduism, Buddhism, Judaism, Christianity, and/or Islam. The second point of the course focuses on how the Humanities and Social Sciences work. We will use methods from various disciplines to study religion-history of religions and religious thought, sociology, anthropology and ethnography, art history, study of myth, philosophy, analysis of religious texts and artifacts (both contemporary and historical), analysis of material culture and the role it plays in religion, and other disciplines and methodologies. We will look at the question of objectivity; is it possible to be objective? We will approach this methodological question using the concept "standpoint." For selected readings, films, and your own writings, we will analyze what the "standpoint" is. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours

LAIS 285 (previously LISS 375). INTRODUCTION TO LAW AND LEGAL SYSTEMS (PH) Examination of different approaches to, principles of, and issues in the law in the U.S. and other societies. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 298 (previously LIHU298). SPECIAL TOPICS Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. Variable credit: 1 to 6 semester hours.

LAIS 299 (previously LIHU 199) INDEPENDENT STUDY Individual research or special problem projects supervised by a faculty member. Primarily for students who have completed their Humanities and Social Science requirements. Instructor consent required. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit: 1 to 6 semester hours.

LAIS 300 (previously LIHU301). CREATIVE WRITING: FICTION (H) Students will write weekly exercises and read their work for the pleasure and edification of the class. The midterm in this course will be the production of a short story. The final will consist of a completed, revised short story. The best of these works may be printed in a future collection. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 301 (previously LIHU 305) CREATIVE WRITING: POETRY I (H) This course focuses on reading and writing poetry. Students will learn many different poetic forms to compliment prosody, craft, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic tools, encourage the writing of literary poetry, and stimulate the development of the student's craft. The purpose of the course is to experience the literature and its place in a multicultural society, while students "try on" various styles and contests in order to develop their own voice. The course enrollment is split between the 300 and 400 levels (see LAIS 401), to allow returning students the opportunity for continued development. An additional book review and presentation, as well as leading the small groups will be expected of returning students. Prerequisite: LAIS 100 (previously LIHU 100). Prerequisite or corequisite: SYGN 200. 3 hours seminar. 3 semester hours.

LAIS 305 (previously LIHU 376) AMERICAN LITERATURE: COLONIAL PERIOD TO THE PRESENT (H). This course offers an overview of American literature from the colonial period to the present. The texts of the class provide a context for examining the traditions that shape the American nation as a physical, cultural and historical space. As we read, we will focus on the relationships between community, landscape, history, and language in the American imagination. We will concentrate specifically on conceptions of the nation and national identity in relation to race, gender, and class difference. Authors may include: Rowlandson, Brown, Apess, Hawthorne, Douglass, Melville, Whitman, James, Stein, Eliot, Hemingway, Silko, and Auster. Prerequisite: LAIS 100 (previously LIHU100) Prerequisite or corequisite: SYGN 200. 3 hours lecture/discussion, 3 semester hours.

LAIS 306 (previously LIHU 377). AFRICAN AMERICAN LITERATURE: FOUNDATIONS TO PRESENT (H). This course is an examination of African-American literature from its origins in black folklore to the present. Students will be introduced to the major texts and cultural productions of the African American tradition. We will examine a diverse collection of materials including slave narratives, autobiographies, essays, and novels, in addition to musical traditions such as spirituals, gospel, ragtime, and blues. The materials of this class offer an opportunity to identify literary characteristics that have evolved out of the culture, language, and historical experience of black people and to examine constructions of race and racial difference in America. Authors may include: Equiano, Douglass, Chesnutt, DuBois, Johnson, Hughes, Hurston, Toomer, Larsen, Wright, Ellison, Hayden, and Morrison. Prerequisite: LAIS 100 (previously LIHU100), prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 314 (previously LIHU 300). THE JOURNEY MOTIF IN MODERN LITERATURE (H) This course will explore the notion that life is a journey, be it a spiritual one to dis-

cover one's self or geographical one to discover other lands and other people. The exploration will rely on the major literary genres—drama, fiction, and poetry—and include authors such as Twain, Hurston, Kerouac, Whitman, and Cormac McCarthy. A discussion course. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 315 (previously LIHU 339). MUSICAL TRADITIONS OF THE WESTERN WORLD (H). An introduction to music of the Western world from its beginnings to the present. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 317 (previously LISS 455). JAPANESE HISTORY AND CULTURE (HI) Japanese History and Culture covers Japan's historical and cultural foundations from earliest times through the modern period. It is designed to allow students who have had three semesters of Japanese language instruction (or the equivalent) to apply their knowledge of Japanese in a social science-based course. Major themes will include: cultural roots; forms of social organization; the development of writing systems; the development of religious institutions; the evolution of legal institutions; literary roots; and clan structure. Prerequisites: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 320 (previously LIHU 325). INTRODUCTION TO ETHICS (HP) A general introduction to ethics that explores its analytic and historical traditions. Reference will commonly be made to one or more significant texts by such moral philosophers as Plato, Aristotle, Augustine, Thomas Aquinas, Kant, John Stuart Mill, and others. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 321 (previously LIHU 326). POLITICAL PHILOSOPHY AND ENGINEERING (H) A critical exploration of how engineering may be related to different philosophies of the common good. Prerequisite: LAIS 100 (previously LIHU100). Corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 322 INTRODUCTION TO LOGIC A general introduction to logic that explores its analytic and historical traditions. Coverage will commonly consider informal and formal fallacies, syllogistic logic, sentential logic, and elementary quantification theory. Reference will commonly be made to the work of such logical theorists as Aristotle, Frege, Russell and Whitehead, Quine, and others. Prerequisite: LAIS 100 (previously LIHU100). Corequisite: SYGN200. 3 hours lecture, 3 credit hours.

LAIS 325 (previously LISS 300). CULTURAL ANTHROPOLOGY (H) A study of the social behavior and cultural development of humans. Prerequisite: LAIS 100 (previously

LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 335 (previously LISS 340). INTERNATIONAL POLITICAL ECONOMY OF LATIN AMERICA (PI) A broad survey of the interrelationship between the state and economy in Latin America as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics of interstate relationships between the developed North and the developing South. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 337 (previously LISS 342). INTERNATIONAL POLITICAL ECONOMY OF ASIA (PI) A broad survey of the interrelationship between the state and economy in East and Southeast Asia as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics of interstate relationships between the developed North and the developing South. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 339 (previously LISS 344). INTERNATIONAL POLITICAL ECONOMY OF THE MIDDLE EAST (PI) A broad survey of the interrelationships between the state and market in the Middle East as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics between the developed North and the developing South. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 341 (previously LISS 346). INTERNATIONAL POLITICAL ECONOMY OF AFRICA (PI) A broad survey of the interrelationships between the state and market in Africa as seen through an examination of critical contemporary and historical issues that shape policy, economy, and society. Special emphasis will be given to the dynamics between the developed North and the developing South. Prerequisite: LAIS 100 (previously LIHU 100). Prerequisite or corequisite: SYGN 200. 3 hours lecture/discussion. 3 semester hours.

LAIS 345 (previously LISS 335). INTERNATIONAL POLITICAL ECONOMY (PI) International Political Economy is a study of contentious and harmonious relationships between the state and the market on the nation-state level, between individual states and their markets on the regional level, and between region-states and region-markets on the global level. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 365 (previously LIHU350). HISTORY OF WAR (H) History of War looks at war primarily as a significant human

activity in the history of the Western World since the times of Greece and Rome to the present. The causes, strategies, results, and costs of various wars will be covered, with considerable focus on important military and political leaders as well as on noted historians and theoreticians. The course is primarily a lecture course with possible group and individual presentations as class size permits. Tests will be both objective and essay types. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 370 (previously LIHU 365) HISTORY OF SCIENCE (PI) An introduction to the social history of science, exploring significant people, theories, and social practices in science, with special attention to the histories of physics, chemistry, earth sciences, ecology, and biology. Prerequisite: LAIS 100 (previously LIHU 100). Prerequisite or co-requisite SYGN 200. 3 hours lecture/discussion. 3 semester hours.

LAIS 371 (previously LIHU 367) HISTORY OF TECHNOLOGY (PI) A survey of the history of technology in the modern period (from roughly 1700 to the present), exploring the role technology has played in the political and social history of countries around the world. Prerequisite: LAIS 100 (previously LIHU 100). Prerequisite or co-requisite SYGN 200. 3 hours lecture/discussion. 3 semester hours.

LAIS 375 (previously LIHU362). ENGINEERING CULTURES (HI) This course seeks to improve students' abilities to understand and assess engineering problem solving from different cultural, political, and historical perspectives. An exploration, by comparison and contrast, of engineering cultures in such settings as 20th century United States, Japan, former Soviet Union and present-day Russia, Europe, South-east Asia, and Latin America. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours lecture/discussion; 3 semester hours.

LAIS 379 (previously LISS 410). UTOPIAS/DYSTOPIAS (H) This course studies the relationship between society, technology, and science using fiction and film as a point of departure. A variety of science fiction novels, short stories, and films will provide the starting point for discussions. These creative works will also be concrete examples of various conceptualizations that historians, sociologists, philosophers, and other scholars have created to discuss the relationship. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 398 (previously LIHU398). SPECIAL TOPICS Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit: 1 to 6 semester hours.

LAIS 399 (previously LIHU 399) INDEPENDENT STUDY Individual research or special problem projects supervised by a faculty member. Primarily for students who have completed their Humanities and Social Science requirements. In-

structor consent required. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit: 1 to 6 semester hours.

Note: Students enrolling in 400-level courses are required to have senior standing or permission of instructor.

LAIS 401 (previously LIHU 405) CREATIVE WRITING: POETRY II (H) This course is a continuation of LAIS 301 (LIHU 305) for those interested in developing their poetry writing further. It focuses on reading and writing poetry. Students will learn many different poetic forms to compliment prosody, craft, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic tools, encourage the writing of literary poetry, and simulate the development of the student's craft. The purpose of the course is to experience the literature and its place in a multicultural society, while students "try on" various styles and contexts in order to develop their own voice. The course enrollment is split between the 300 and 400 levels to allow returning students the opportunity for continued development. An additional book review and presentation, as well as leading the small groups will be expected of returning students. Prerequisite: LAIS 301 (LIHU 305). Prerequisite or corequisite: SYGN 200. 3 hours seminar. 3 semester.

LAIS 402 (previously LIHU 412) WRITING PROPOSALS FOR A BETTER WORLD (HP) This course develops the student's writing and higher-order thinking skills and helps meet the needs of underserved populations, particularly via funding proposals written for nonprofit organizations. Prerequisite: LAIS 100 (previously LIHU 100). Prerequisite or corequisite: SYGN 200. 3 semester hours.

LAIS 405 (previously LIHU 470). BECOMING AMERICAN: LITERARY PERSPECTIVES (H) This course will explore the increasing heterogeneity of U.S. society by examining the immigration and assimilation experience of Americans from Europe, Africa, Latin America, and Asia as well as Native Americans. Primary sources and works of literature will provide the media for examining these phenomena. In addition, Arthur Schlesinger, Jr.'s thesis about the 'unifying ideals and common culture' that have allowed the United States to absorb immigrants from every corner of the globe under the umbrella of individual freedom, and the various ways in which Americans have attempted to live up to the motto 'e pluribus unum' will also be explored. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 406 (previously LIHU 401). THE AMERICAN DREAM: ILLUSION OR REALITY? (H) This seminar will examine 'that elusive phrase, the American dream,' and ask what it meant to the pioneers in the New World, how it withered, and whether it has been revived. The concept will be critically scrutinized within cultural contexts. The study will rely on the major genres of fiction, drama, and poetry, but

will venture into biography and autobiography, and will range from Thoreau's *Walden* to Kerouac's *On the Road* and Boyle's *Budding Prospects*. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 409 (previously LIHU 406) SHAKESPEAREAN DRAMA (H) Shakespeare, the most well known writer in English and perhaps the world, deals with universal themes and the ultimate nature of what it is to be a human being. His plays are staged, filmed, and read around the globe, even after 400 years. This seminar will explore why Shakespeare's plays and characters have such lasting power and meaning to humanity. The seminar will combine class discussion, lecture, and video. Grades will be based on participation, response essays, and a final essay. Prerequisite: LAIS 100 (previously LIHU 100). Prerequisite or corequisite: SYGN 200. 3 hours seminar. 3 semester hours.

LAIS 414 (previously LIHU 402). HEROES AND ANTI-HEROES: A TRAGIC VIEW (H) This course features heroes and antiheroes (average folks, like most of us), but because it is difficult to be heroic unless there are one or more villains lurking in the shadows, there will have to be an Iago or Caesar or a politician or a member of the bureaucracy to overcome. Webster's defines heroic as 'exhibiting or marked by courage and daring.' Courage and daring are not confined to the battlefield, of course. One can find them in surprising places—in the community (Ibsen's *Enemy of the People*), in the psychiatric ward (Kesey's *One Flew Over the Cuckoo's Nest*), in the military (Heller's *Catch-22*), on the river (Twain's *The Adventures of Huckleberry Finn* or in a "bachelor pad" (Simon's *Last of the Red Hot Lovers*). Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 420 (previously LIHU 420) BUSINESS, ENGINEERING AND LEADERSHIP ETHICS (HP) A critical exploration of business, management, engineering, and leadership ethics, with an emphasis on relations among these fields of practice. 3 hours seminar/discussion; 3 semester hours.

LAIS 435 (previously LISS 440). LATIN AMERICAN DEVELOPMENT (I) A senior seminar designed to explore the political economy of current and recent past development strategies, models, efforts, and issues in Latin America, one of the most dynamic regions of the world today. Development is understood to be a nonlinear, complex set of processes involving political, economic, social, cultural, and environmental factors whose ultimate goal is to improve the quality of life for individuals. The role of both the state and the market in development processes will be examined. Topics to be covered will vary as changing realities dictate but will be drawn from such subjects as inequality of income distribution; the role of education and health care; region-markets; the impact of globalization; institution-building; corporate-community-state interfaces; neoliberalism; privati-

zation; democracy; and public policy formulation as it relates to development goals. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 436 (previously LISS 441). HEMISPHERIC INTEGRATION IN THE AMERICAS (I) This international political economy seminar is designed to accompany the endeavor now under way in the Americas to create a free trade area for the entire Western Hemisphere. Integrating this hemisphere, however, is not just restricted to the mechanics of facilitating trade but also engages a host of other economic, political, social, cultural, and environmental issues, which will also be treated in this course. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 437 (previously LISS 442) ASIAN DEVELOPMENT (I) This international political economy seminar deals with the historical development of Asia Pacific from agrarian to post-industrial eras; its economic, political, and cultural transformation since World War II, contemporary security issues that both divide and unite the region; and globalization processes that encourage Asia Pacific to forge a single trading bloc. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 441 (previously LISS 446). AFRICAN DEVELOPMENT (I) This course provides a broad overview of the political economy of Africa. Its goal is to give students an understanding of the possibilities of African development and the impediments that currently block its economic growth. Despite substantial natural resources, mineral reserves, and human capital, most African countries remain mired in poverty. The struggles that have arisen on the continent have fostered thinking about the curse of natural resources where countries with oil or diamonds are beset with political instability and warfare. Readings give first an introduction to the continent followed by a focus on the specific issues that confront African development today. Prerequisite: LAIS 100 (previously LIHU 100). Prerequisite or co-requisite: SYGN 200. 3 hours seminar. 3 semester.

LAIS 442 (previously LISS 447) NATURAL RESOURCES AND WAR IN AFRICA (I) Africa possesses abundant natural resources yet suffers civil wars and international conflicts based on access to resource revenues. The course examines the distinctive history of Africa, the impact of the resource curse, mismanagement of government and corruption, and specific cases of unrest and war in Africa. Prerequisite: LAIS 100 (previously LIHU 100). Prerequisite or corequisite: SYGN 200. 3 hours seminar. 3 semester hours.

LAIS 446 (previously LISS 430). GLOBALIZATION (I) This international political economy seminar is an historical and contemporary analysis of globalization processes examined through selected issues of world affairs of political, eco-

conomic, military, and diplomatic significance. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 447 (previously LISS 433). GLOBAL CORPORATIONS (I) This international political economy seminar seeks to (1) understand the history of the making of global corporations and their relationship to the state, region-markets, and region-states; and (2) analyze the on-going changes in global, regional, and national political economies due to the presence of global corporations. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 448 (previously LISS 431). GLOBAL ENVIRONMENTAL ISSUES (I) Critical examination of interactions between development and the environment and the human dimensions of global change; social, political, economic, and cultural responses to the management and preservation of natural resources and ecosystems on a global scale. Exploration of the meaning and implications of “Stewardship of the Earth” and “Sustainable Development.” Prerequisite: LAIS100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 449 (previously LISS 432). CULTURAL DYNAMICS OF GLOBAL DEVELOPMENT (I) Role of cultures and nuances in world development; cultural relationship between the developed North and the developing South, specifically between the U.S. and the Third World. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 450 (previously LISS 435). POLITICAL RISK ASSESSMENT (I) This course will review the existing methodologies and techniques of risk assessment in both country-specific and global environments. It will also seek to design better ways of assessing and evaluating risk factors for business and public diplomacy in the increasingly globalized context of economy and politics wherein the role of the state is being challenged and redefined. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. Prerequisite: At least one IPE 300- or 400-level course and permission of instructor. 3 hours seminar; 3 semester hours.

LAIS 451 (previously LISS 439). POLITICAL RISK ASSESSMENT RESEARCH SEMINAR (I) This international political economy seminar must be taken concurrently with LISS435, 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: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. Concurrent enrollment in LAIS 450 (previously LISS435). 1 hour seminar; 1 semester hour.

LAIS 452 (previously LISS 437). CORRUPTION AND DEVELOPMENT (I) This course 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 bribe taking might occur. Prerequisite: LAIS 100 (previously LIHU 100). Prerequisite or corequisite: SYGN 200. 3 hours seminar. 3 semester hours.

LAIS 459 (previously LISS 434). INTERNATIONAL FIELD PRACTICUM (I) For students who go abroad for an on-site practicum involving their technical field as practiced in another country and culture; required course for students pursuing a certificate in International Political Economy; all arrangements for this course are to be supervised and approved by the advisor of the International Political Economy minor program. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 465 (previously LIHU 479). THE AMERICAN MILITARY EXPERIENCE (H) A survey of military history, with primary focus on the American military experience from 1775 to present. Emphasis is placed not only on military strategy and technology, but also on relevant political, social, and economic questions. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours. Open to ROTC students or by permission of the LAIS Division.

LAIS 470 (previously LISS 461). TECHNOLOGY AND GENDER: ISSUES (HP) This course focuses on how women and men relate to technology. Several traditional disciplines will be used: philosophy, history, sociology, literature, and a brief look at theory. The class will begin discussing some basic concepts such as gender and sex and the essential and/or social construction of gender, for example. We will then focus on topical and historical issues. We will look at modern engineering using sociological studies that focus on women in engineering. We will look at some specific topics including military technologies, ecology, and reproductive technologies. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 475 (previously LIHU 363). ENGINEERING CULTURES IN THE DEVELOPING WORLD (HI) An investigation and assessment of engineering problem solving in the developing world using historical and cultural cases. Countries to be included range across Africa, Asia, and Latin America. Prerequisite: LAIS 100 (previously LIHU100). Corequisite: SYGN200. 3 hours lecture/ discussion; 3 semester hours.

LAIS 476 (previously LIHU 460) TECHNOLOGY AND INTERNATIONAL DEVELOPMENT (HI) An historical

examination of the role of technology in humanitarian and social improvement projects. Prerequisite: LAIS 100 (previously LIHU 100). Corequisite: SYGN 200. 3 hours lecture/discussion; 3 semester hours.

LAIS 485 (previously LISS 474). CONSTITUTIONAL LAW AND POLITICS (HP) This course presents a comprehensive survey of the U.S. Constitution with special attention devoted to the first ten Amendments, also known as the Bill of Rights. Since the Constitution is primarily a legal document, the class will adopt a legal approach to constitutional interpretation. However, as the historical and political context of constitutional interpretation is inseparable from the legal analysis, these areas will also be covered. Significant current developments in constitutional jurisprudence will also be examined. The first part of the course deals with Articles I through III of the Constitution, which specify the division of national governmental power among the executive, legislative, and judicial branches of government. Additionally, the federal nature of the American governmental system, in which governmental authority is apportioned between the national government and the state governments, will be studied. The second part of the course examines the individual rights specifically protected by the amendments to the Constitution, principally the First, Fourth, Fifth, Sixth, Eighth, and Fourteenth Amendments. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 486 (previously LISS 462). SCIENCE AND TECHNOLOGY POLICY (HP) An examination of current issues relating to science and technology policy in the United States and, as appropriate, in other countries. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 487 (previously LISS 480). ENVIRONMENTAL POLITICS AND POLICY (P) Seminar on environmental policies and the political and governmental processes that produce them. Group discussion and independent research on specific environmental issues. Primary but not exclusive focus on the U.S. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 488 (previously LISS 482). WATER POLITICS AND POLICY (P) Seminar on water policies and the political and governmental processes that produce them, as an exemplar 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. Prerequisite: LAIS 100 (previously LIHU100). Prerequisite or corequisite: SYGN200. 3 hours seminar; 3 semester hours.

LAIS 498 (previously LIHU498). SPECIAL TOPICS Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit: 1 to 6 semester hours.

LAIS 499 (previously LIHU 499) INDEPENDENT STUDY Individual research or special problem projects supervised by a faculty member. Primarily for students who have completed their Humanities and Social Science requirements. Instructor consent required. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit: 1 to 6 semester hours.

Foreign Languages (LIFL)

A variety of foreign languages is available through the LAIS Division. Students interested in a particular language should check with the LAIS Division Office to determine when these languages might be scheduled. In order to gain basic proficiency from their foreign language study, students are encouraged to enroll for at least two semesters in whatever language(s) they elect to take. If there is sufficient demand, the Division can provide third- and fourth-semester courses in a given foreign language. **No student is permitted to take a foreign language that is either his/her native language or second language.** Proficiency tests may be used to determine at what level a student should be enrolled, but a student cannot receive course credit by taking these tests.

Foreign Language Policy

Students will not receive credit toward their LAIS or Free Elective graduation requirements for taking a foreign language in which they have had previous courses as per the following formula:

If a student has taken one year in high school or one semester in college, he/she will not receive graduation credit for the first semester in a CSM foreign language course. Likewise, if a student has taken two years in high school or two semesters in college, he/she will not receive graduation credit for the second semester, and if a student has taken three years in high school or three semesters in college, he/she will not receive graduation credit for the third semester.

LIFL 113 (previously LIFL 221). SPANISH I (HI) Fundamentals of spoken and written Spanish with an emphasis on vocabulary, idiomatic expressions of daily conversation, and Spanish American culture. 3 semester hours.

LIFL 123 (previously LIFL 321). SPANISH II (HI) Continuation of Spanish I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL 213 (previously LIFL 421). SPANISH III (HI) Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL 114 (previously LIFL 222). ARABIC I (HI) Fundamentals of spoken and written Arabic with an emphasis on vocabulary, idiomatic expressions of daily conversation, and culture of Arabic-speaking societies. 3 semester hours.

LIFL 124 (previously LIFL 322). ARABIC II (HI) Continuation of Arabic I with an emphasis on acquiring conversa-

tional skills as well as further study of grammar, vocabulary, and culture of Arabic speaking societies. 3 semester hours.

LIFL 214 (previously LIFL 422). ARABIC III (HI) Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and culture of Arabic-speaking societies. 3 semester hours.

LIFL 115 (previously LIFL 223). GERMAN I (HI) Fundamentals of spoken and written German with an emphasis on vocabulary, idiomatic expressions of daily conversation, and German culture. 3 semester hours.

LIFL 125 (previously LIFL 323). GERMAN II (HI) Continuation of German I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and German culture. 3 semester hours.

LIFL 215 (previously LIFL 423). GERMAN III (HI) Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and German culture. 3 semester hours.

LIFL 116 (previously LIFL 224). RUSSIAN I (HI) Fundamentals of spoken and written Russian with an emphasis on vocabulary, idiomatic expressions of daily conversation, and Russian culture. 3 semester hours.

LIFL 126 (previously LIFL 324). RUSSIAN II (HI) Continuation of Russian I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and Russian culture. 3 semester hours.

LIFL 216 (previously LIFL 424). RUSSIAN III (HI) Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and Russian culture. 3 semester hours.

LIFL 117 (previously LIFL 226). PORTUGUESE I (HI) Fundamentals of spoken and written Portuguese with an emphasis on vocabulary, idiomatic expressions of daily conversation, and Brazilian culture. 3 semester hours.

LIFL 127 (previously LIFL 326). PORTUGUESE II (HI) Continuation of Portuguese I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and Brazilian culture. 3 semester hours.

LIFL 217 (previously LIFL 426). PORTUGUESE III (HI) Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and Brazilian culture. 3 semester hours.

LIFL 118 (previously LIFL 229). JAPANESE I (HI) Fundamentals of spoken and written Japanese with an emphasis on vocabulary, idiomatic expressions of daily conversation, and Japanese culture. 3 semester hours.

LIFL 128 (previously LIFL 329). JAPANESE II (HI) Continuation of Japanese I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and Japanese culture. 3 semester hours.

LIFL 218 (previously LIFL 429). JAPANESE III (HI) Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and Japanese culture. 3 semester hours.

LIFL 198, 298, 398, and 498. SPECIAL TOPICS Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit: 1 to 6 semester hours.

LIFL 199, 299, 399, and 499. INDEPENDENT STUDY Individual research or special problem projects supervised by a faculty member. Instructor consent required. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit: 1 to 6 semester hours.

Communication (LICM)

Courses in communication do not count toward the LAIS restricted elective requirement but may be taken for free elective credit and to complete a communications minor or Area of Special Interest (ASI).

LICM301. ORAL COMMUNICATION 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.

LICM306. SELECTED TOPICS IN WRITTEN COMMUNICATION Information on courses designated by this number may be obtained from the LAIS Division. Will depend on the level of the specific course. 1 to 3 hours lecture/lab; variable credit: 1 to 3 semester hours.

Music (LIMU)

A cultural opportunity for students with music skills to continue study in music for a richer personal development. Free elective hours required by degree-granting departments may be satisfied by a maximum of 3 semester hours total of concert band (i.e., spring semester), chorus, or physical education and athletics.

LIMU101, 102, 201, 202, 301, 302, 401, 402. BAND Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour.

LIMU111, 112, 211, 212, 311, 312, 411, 412. CHORUS Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour.

LIMU340. MUSIC THEORY The course begins with the fundamentals of music theory and moves into their more complex applications. Music of the common practice period is considered. Aural and visual recognition of harmonic materials covered is emphasized. Prerequisite: LAIS 339 (previously LIHU339) or consent of instructor. 3 hours lecture/discussion; 3 semester hours.

(See also LIHU339. MUSICAL TRADITIONS OF THE WESTERN WORLD in preceding list of LAIS courses.)

LIMU 350 MUSIC TECHNOLOGY An introduction to the physics of music and sound. The history of music technology from wax tubes to synthesizers. Construction of instruments and studio. 3 hours lecture. 3 semester hours.

LIMU 401 JAZZ ENSEMBLE/PEP BAND - FALL The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance (s). 1 semester hour.

LIMU 402 JAZZ ENSEMBLE/PEP BAND - SPRING The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour.

LIMU 403 JAZZ LAB The Jazz Lab provides an opportunity for students to participate in a musical ensemble in the jazz combo format. Jazz music is a unique American art form. The jazz combo format is an exciting way for students to experience the joy and sense of achievement of performing this great American music form. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour.

Systems (SYGN)

SYGN200. HUMAN SYSTEMS Human Systems is an interdisciplinary historical examination of key systems created by humans—namely, political, economic, social, and cultural institutions—as they have evolved worldwide from the inception of the modern era (ca. 1500) to the present. This course embodies an elaboration of these human systems as introduced in their environmental context in Nature and Human Values and will reference themes and issues explored therein. It also demonstrates the cross-disciplinary applicability of the ‘systems’ concept. Assignments will give students continued practice in writing. Prerequisite: LAIS 100 (previously LIHU100). 3 hours lecture/discussion; 3 semester hours).

Mathematical and Computer Sciences

GRAEME FAIRWEATHER, Professor and Department Head
BERNARD BIALECKI, Professor
MAHADEVAN GANESH, Professor
WILLY HEREMAN, Professor
PAUL A. MARTIN, Professor
DINESH MEHTA, Professor
WILLIAM C. NAVIDI, Professor
TRACY CAMP, Associate Professor
BARBARA M. MOSKAL, Associate Professor
LUIS TENORIO, Associate Professor
MICHAEL COLAGROSSO, Assistant Professor
REINHARD FURRER, Assistant Professor
QI HAN, Assistant Professor
JAE YOUNG LEE, Assistant Professor
XIAOWEN (JASON) LIU, Assistant Professor
HUGH KING, Senior Lecturer
CYNDI RADER, Senior Lecturer
TERRY BRIDGMAN, Lecturer
G. GUSTAVE GREIVEL, Lecturer
ROMAN TANKELEVICH, Lecturer
SCOTT STRONG, Instructor
WILLIAM R. ASTLE, Professor Emeritus
NORMAN BLEISTEIN, Professor Emeritus
ARDEL J. BOES, Professor Emeritus
AUSTIN R. BROWN, Professor Emeritus
RAYMOND R. GUTZMAN, Professor Emeritus
FRANK G. HAGIN, Professor Emeritus
DONALD C.B. MARSH, Professor Emeritus
STEVEN PRUESS, Professor Emeritus
ROBERT E. D. WOOLSEY, Professor Emeritus
BARBARA B. BATH, Associate Professor Emerita
RUTH MAURER, Associate Professor Emerita
ROBERT G. UNDERWOOD, Associate Professor Emeritus

Program Description

The Mathematical and Computer Sciences Department (MCS) offers an undergraduate degree in which the student may select a program in the mathematical and computer sciences. There are three tracks: (i) the Computational and Applied Mathematics (CAM) option, (ii) the Statistics option, and (iii) the Computer Sciences option. Each track offers a unique opportunity to study mathematical and computer sciences in an engineering environment. All three tracks emphasize technical competence, problem solving, teamwork, projects, relation to other disciplines, and verbal, written, and graphical skills.

The department provides the teaching skills and technical expertise to develop mathematical and computer sciences capabilities for all Colorado School of Mines students. In addition, MCS programs support targeted undergraduate majors in mathematical and computer sciences and also graduate degree programs relevant to mathematical and computer sciences aspects of the CSM mission.

In a broad sense, these programs stress the development of practical applications techniques to enhance the overall attractiveness of mathematical and computer sciences majors to a wide range of employers in industry. More specifically, we utilize a summer "field session" program in Computer Science and the senior capstone experiences in Computational and Applied Mathematics, and Statistics to engage high level undergraduate students in problems of practical applicability for potential employers. These courses are designed to simulate an industrial job or research environment. The close collaboration with potential employers or professors improves communication between our students and the private sector as well as with sponsors from other disciplines on campus.

Mathematical and Computer Sciences majors can use their free electives to take additional courses of special interest to them. This adds to the flexibility of the program and qualifies students for a wide variety of careers.

Any program of this type requires emphasis in study areas which utilize the special skills of the Department. These areas are:

Computational and Applied Mathematics: Classical scattering theory, dynamical systems, nonlinear partial differential equations, numerical analysis, symbolic computing, and mathematics education.

Applied Computer Sciences: Artificial intelligence, neural networks, parallel processing, pattern recognition, computer vision, computer graphics, databases, and fuzzy set theory.

Applied Statistics: Stochastic modeling, Monte Carlo methods, biostatistics, statistical genetics, statistical methods in cosmology, and inverse problems.

Program Educational Objectives (Bachelor of Science in Mathematical and Computer Sciences)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the Mathematical and Computer Sciences Program at CSM has established the following program educational objectives:

Students will demonstrate technical expertise within mathematics/computer science by:

Designing and implementing solutions to practical problems in science and engineering,

Using appropriate technology as a tool to solve problems in mathematics/computer science, and

Creating efficient algorithms and well structured computer programs.

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

Extending course material to solve original problems,

Applying knowledge of mathematics/computer science to the solution of problems,

Identifying, formulating and solving mathematics/computer science problems, and

Analyzing and interpreting statistical data.

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

Applying mathematics/computer science to solve problems in other fields,

Working in cooperative multi-disciplinary teams, and

Choosing appropriate technology to solve problems in other disciplines.

Students will demonstrate an ability to communicate mathematics/computer science effectively by:

Giving oral presentations,

Completing written explanations,

Interacting effectively in cooperative teams,

Creating well documented programs, and

Understanding and interpreting written material in mathematics/computer science.

Curriculum

The calculus sequence emphasizes mathematics applied to problems students are likely to see in other fields. This supports the curricula in other programs where mathematics is important, and assists students who are underprepared in mathematics. Priorities in the mathematics curriculum include:

applied problems in the mathematics courses and

ready utilization of mathematics in the science and engineering courses.

This emphasis on the utilization of mathematics and computer sciences continues through the upper division courses. Another aspect of the curriculum is the use of a spiraling mode of learning in which concepts are revisited to deepen the students' understanding. The applications, team work, assessment, and communications emphasis directly address ABET criteria and the CSM graduate profile. The curriculum offers the following three study options:

Degree Requirements (Mathematical and Computer Sciences)

Computational and Applied Mathematics Option

Sophomore Year Fall Semester	lec.	lab.	sem.hrs.
MACS213 Calc. for Scientists & Eng. III	4		4
MACS261 Programming Concepts	3		3
EPIC251 Design II	2	3	3
PHGN200 Physics II	3.5	3	4.5
*EBGN201 Principles of Economics/ SYGN200 Systems	3		3
PAGN201 Physical Education III		2	0.5
Total			18

Sophomore Year Spring Semester			
	lec.	lab.	sem.hrs.
MACS262 Data Structures	3		3
MACS315 Differential Equations	3		3
MACS342 Honors Linear Algebra	3		3
*SYGN200 Systems/EBGN201	3		3
LAIS/EBGN - H&SS Cluster Elective I	3		3
PAGN202 Physical Education IV	2		0.5
Total			15.5

*Student can choose order of EBGN201 and SYGN 200

Summer Field Session			
	lec.	lab.	sem.hrs.
MACS300 Foundations of Advanced Math.			4
Total			4

Junior Year Fall Semester			
	lec.	lab.	sem.hrs.
MACS334 Introduction to Probability	3		3
MACS401 Introduction to Analysis	3		3
MACS407 Introduction to Scientific Computing	3		3
LAIS/EBGN - H&SS Cluster Elective II	3		3
Free Elective	3		3
Free Elective	3		3
Total			18

Junior Year Spring Semester			
	lec.	lab.	sem.hrs.
MACS454 Complex Analysis	3		3
MACS458 Abstract Algebra	3		3
MACS Elective - Mathematics	3		3
Free Elective	3		3
Free Elective	3		3
Total			15

Senior Year Fall Semester			
	lec.	lab.	sem.hrs.
MACS433 Mathematical Biology	3		3
MACS441 Computer Graphics	3		3
MACS455 Partial Differential Equations	3		3
LAIS/EBGN H&SS Cluster Elective III	3		3
Free Elective	3		3
Total			15

Senior Year Spring Semester			
	lec.	lab.	sem.hrs.
MACS440 Parallel Computing	3		3
MACS484 Math. & Comp. Modeling (Capstone)	3		3
MACS Elective - Mathematics	3		3
MACS Elective - Mathematics	3		3
Free Elective	3		3
Total			15

Degree Total 133.5

Statistics Option

Sophomore Year Fall Semester			
	lec.	lab.	sem.hrs.
MACS213 Calc. for Scientists & Eng. III	4		4
MACS261 Programming Concepts	3		3
EPIC251 Design II	2	3	3
PHGN200 Physics II	3.5	3	4.5
*EBGN201 Principles of Economics/ SYGN200 Systems	3		3
PAGN201 Physical Education III		2	0.5
Total			18

Sophomore Year Spring Semester			
	lec.	lab.	sem.hrs.
MACS262 Data Structures	3		3
MACS315 Differential Equations	3		3
MACS342 Honors Linear Algebra	3		3
*SYGN200 Systems/EBGN201	3		3
LAIS/EBGN - H&SS Cluster Elective I	3		3
PAGN202 Physical Education IV	2		0.5
Total			15.5

*Student can choose order of EBGN201 and SYGN 200

Summer Field Session			
	lec.	lab.	sem.hrs.
MACS300 Foundations of Advanced Math.			4
Total			4

Junior Year Fall Semester			
	lec.	lab.	sem.hrs.
MACS334 Introduction to Probability	3		3
MACS401 Introduction to Analysis	3		3
MACS407 Introduction to Scientific Computing	3		3
LAIS/EBGN - H&SS Cluster Elective II	3		3
Free Elective	3		3
Free Elective	3		3
Total			18

Junior Year Spring Semester			
	lec.	lab.	sem.hrs.
MACS335 Introduction to Statistics	3		3
MACS458 Abstract Algebra	3		3
MACS Elective - Mathematics	3		3
Free Elective	3		3
Free Elective	3		3
Total			15

Senior Year Fall Semester			
	lec.	lab.	sem.hrs.
MACS424 Introduction to Applied Statistics	3		3
MACS433 Mathematical Biology	3		3
MACS438 Stochastic Models	3		3
LAIS/EBGN H&SS Cluster Elective III	3		3
Free Elective	3		3
Total			15

Senior Year Spring Semester			
	lec.	lab.	sem.hrs.
MACS436 Advanced Statistical Modeling	3		3
MACS482 Statistics Practicum (Capstone)	3		3
MACS Elective - Mathematics	3		3
MACS Elective - Mathematics	3		3
Free Elective	3		3
Total			15

Degree Total 133.5

Computer Sciences Option

Sophomore Year Fall Semester			
	lec.	lab.	sem.hrs.
MACS213 Calc. for Scientists & Eng. III	4		4
MACS261 Programming Concepts	3		3
EPIC251 Design II	3	1	3
PHGN200 Physics II	3	3	4.5
EBGN201 Principles of Economics/ SYGN200 Systems	3		3
PAGN201 Physical Education III		2	0.5
Total			18

Sophomore Year Spring Semester	lec.	lab.	sem.hrs.
MACS262 Data Structures	3		3
MACS315 Differential Equations	3		3
MACS332 Linear Algebra	3		3
*SYGN200 Systems/EBGN201	3		3
Free Elective	3		3
PAGN202 Physical Education IV		2	0.5
Total			15.5

*Student can choose order of EBGN201 and SYGN200

Junior Year Fall Semester	lec.	lab.	sem.hrs.
MACS306 Software Engineering	3		3
MACS323 Prob. & Stat. for Engineers	3		3
MACS341 Mach. Org. & Assembly Lang. Prog.	3		3
MACS358 Discrete Math & Algebraic Struct.	3		3
Area of Special Interest	3		3
Total			15

Junior Year Spring Semester	lec.	lab.	sem.hrs.
MACS406 Dsgn. & Analysis of Algorithms	3		3
MACS407 Intro to Scientific Computing	3		3
MACS Elective – Computer Science	3		3
LAIS/EBGN H&SS Cluster Elective I	3		3
Area of Special Interest	3		3
Total			15

Summer Field Session	lec.	lab.	sem.hrs.
MACS370 Field Course (six weeks)			6
Total			6

Senior Year Fall Semester	lec.	lab.	sem.hrs.
MACS442 Operating Systems	3		3
MACS461 Senior Seminar I	1		1
MACS Elective – Computer Science	3		3
Area of Special Interest	3		3
Free elective	3		3
LAIS/EBGN H&SS Cluster Elective II	3		3
Total			16

Senior Year Spring Semester	lec.	lab.	sem.hrs.
MACS400 Princ. of Programming Languages	3		3
MACS462 Senior Seminar II	1		1
MACS Elective – Computer Science	3		3
LAIS/EBGN H&SS Cluster Elective III	3		3
Free elective	3		3
Area of Special Interest	3		3
Total			16

Degree Total 134.5

Minor/ASI Mathematical and Computer Sciences Mathematical Sciences

For an Area of Special Interest in Mathematical Sciences, the student should take the following:

- MACS323 Probability and Statistics for Engineers
- MACS332 Linear Algebra
- MACS333 Introduction to Mathematical Modeling
- MACS407 Introduction to Scientific Computing

For the Minor in Mathematical Sciences, the student should take the following courses in addition to those listed for the ASI:

Two additional 400-level Mathematics courses

Computer Science

For an Area of Special Interest in Computer Sciences, the student should take:

- MACS262 Data Structures
- MACS306 Software Engineering
- MACS341 Machine Organization and Assembly Language Programming –or–
- MACS358 Discrete Mathematics & Algebraic Structures
- MACS406 Design and Analysis of Algorithms –or–
- MACS407 Introduction to Scientific Computing

For the Minor in Computer Sciences, the student should take:

- MACS262 Data Structures
- MACS306 Software Engineering
- MACS341 Machine Organization and Assembly Language Programming
- MACS406 Design and Analysis of Algorithms –or–
- MACS407 Introduction to Scientific Computing

and two 400-level courses, which may not be languages transferred from another university.

Combined BS/MS in Mathematical and Computer Sciences

The Department of Mathematical and Computer Sciences offers a combined Bachelor of Science/Master of Science program in both Computer Science and Applied Mathematics that enables students to complete a Bachelor of Science and a Master of Science simultaneously. The student takes an additional 30 credit hours of coursework at the graduate level, in addition to the undergraduate requirements, and completes both degrees at the same time. Interested students should contact the department for further information.

Description of Courses

MACS100. INTRODUCTORY TOPICS FOR CALCULUS (S) An introduction and/or review of topics which are essential to the background of an undergraduate student at CSM. This course serves as a preparatory course for the Calculus curriculum and includes material from Algebra, Trigonometry, Mathematical Analysis, and Calculus. Topics include basic algebra and equation solving, solutions of inequalities, trigonometric functions and identities, functions of a single variable, continuity, and limits of functions. Prerequisite: Consent of Instructor. 1 semester hour.

MACS111. CALCULUS FOR SCIENTISTS AND ENGINEERS I (I, II, S) First course in the calculus sequence, including elements of plane geometry. Functions, limits, continuity, derivatives and their application. Definite and indefinite integrals; Prerequisite: precalculus. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MACS112. CALCULUS FOR SCIENTISTS AND ENGINEERS II (I, II, S) Vectors, applications and techniques of integration, infinite series, and an introduction to multivariate

functions and surfaces. Prerequisite: MACS111. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MACS122. CALCULUS FOR SCIENTISTS AND ENGINEERS II HONORS (I) Same topics as those covered in MACS112 but with additional material and problems. Prerequisite: Consent of Department. 4 hours lecture; 4 semester hours.

MACS198. SPECIAL TOPICS (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. Prerequisite: Consent of Instructor. Variable credit: 1 to 6 semester hours.

MACS199. INDEPENDENT STUDY (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: 1 to 6 credit hours.

Sophomore Year

MACS213. CALCULUS FOR SCIENTISTS AND ENGINEERS III (I, II, S) Multivariable calculus, including partial derivatives, multiple integration, and vector calculus. Prerequisite: MACS112 or MACS122. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MACS223. CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS (II) Same topics as those covered in MACS213 but with additional material and problems. Prerequisite: Consent of Department. 4 hours lecture; 4 semester hours.

MACS224. CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS(AP) (I) Early introduction of vectors, linear algebra, multivariable calculus. Vector fields, line and surface integrals. Prerequisite: Consent of Department. 4 hours lecture; 4 semester hours.

MACS260 FORTRAN PROGRAMMING (I, II) Computer programming in Fortran90/95 with applications to science and engineering. Program design and structure, problem analysis, debugging, program testing. Language skills: arithmetic, input/output, branching and looping, functions, arrays, data types. Introduction to operating systems. Prerequisite: none. 2 hours lecture; 2 semester hours.

MACS261 PROGRAMMING CONCEPTS (I, II, S) Computer programming in a contemporary language such as C++ or Java, using software engineering techniques. Problem solving, program design, documentation, debugging practices. Language skills: input/output, control, repetition, functions, files, classes and abstract data types, arrays, and pointers. Introduction to operating systems and object-oriented programming. Application to problems in science and engineering. Prerequisite: none. 3 hours lecture; 3 semester hours.

MACS262 DATA STRUCTURES (I, II, S) Defining and using data structures such as linked lists, stacks, queues, binary trees, binary heap, hash tables. Introduction to algorithm analysis, with emphasis on sorting and search routines. Language skills: abstract data types, templates and inheritance. Prerequisite: MACS261. 3 hours lecture; 3 semester hours.

MACS298. SPECIAL TOPICS (I, II, S) Selected topics chosen from special interests of instructor and students. Prerequisite: Consent of Department Head. 1 to 3 semester hours.

MACS299. INDEPENDENT STUDY (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: 1 to 6 credit hours.

MACS300. FOUNDATIONS OF ADVANCED MATHEMATICS (S) (WI) This course is an introduction to communication in mathematics as well computational tools for mathematics. This writing intensive course provides a transition from the Calculus sequence to the upper-division mathematics curriculum at CSM. Topics include logic and recursion, techniques of mathematical proofs, reading and writing proofs, mathematics software. Prerequisites: MACS213, MACS223 or MACS224. 2 hours lecture, 1 hour seminar, 2 hours lab; 4 semester hours.

Junior Year

MACS306. SOFTWARE ENGINEERING (I, II) Introduction to the software life cycle, including planning, design, implementation and testing. Topics include top down program design, problem decomposition, iterative refinement, program modularity and abstract data types. Course work emphasizes good programming practices via models, metrics and documents created and used throughout the software engineering process. Prerequisite: MACS262. 3 hours lecture; 3 semester hours.

MACS315. DIFFERENTIAL EQUATIONS (I, II, S) Classical techniques for first and higher order equations and systems of equations. Laplace transforms. Phase plane and stability analysis of non-linear equations and systems. Applications to physics, mechanics, electrical engineering, and environmental sciences. Prerequisite: MACS213, MACS223 or MACS224. 3 hours lecture; 3 semester hours.

MACS323. PROBABILITY AND STATISTICS FOR ENGINEERS I (I, II, S) Elementary probability, propagation of error, discrete and continuous probability models, interval estimation, hypothesis testing, and linear regression with emphasis on applications to science and engineering. Prerequisite: MACS213, MACS223 or MACS224. 3 hours lecture; 3 semester hours.

MACS324. PROBABILITY AND STATISTICS FOR ENGINEERS II (II) Continuation of MACS323. Multiple regression analysis, analysis of variance, basic experimental

design, and distribution-free methods. Applications emphasized. Prerequisite: MACS323 or consent of instructor. 3 hours lecture; 3 semester hours.

MACS325. DIFFERENTIAL EQUATIONS WITH HONORS (II) Same topics as those covered in MACS315 but with additional material and problems. Prerequisite: Consent of Department. 3 hours lecture; 3 semester hours.

MACS332. LINEAR ALGEBRA (I, II) Systems of linear equations, matrices, determinants and eigenvalues. Linear operators. Abstract vector spaces. Applications selected from linear programming, physics, graph theory, and other fields. Prerequisite: MACS213, MACS223 or MACS224. 3 hours lecture; 3 semester hours.

MACS333. INTRODUCTION TO MATHEMATICAL MODELING. (II) This course gives students the opportunity to build mathematical models of real-world phenomena. It considers several practical problems drawn from engineering and the sciences. For each, the problem is defined and then the student discovers how the underlying principles lead to a mathematical model. The course concentrates on difference and differential equation models. In each case, the student solves the model and analyzes how the model and its solutions are useful in understanding the original problem. Prerequisites: MACS315, MACS325 or consent of instructor. 3 hours lecture; 3 semester hours.

MACS334. INTRODUCTION TO PROBABILITY (I) An introduction to the theory of probability essential for problems in science and engineering. Topics include axioms of probability, combinatorics, conditional probability and independence, discrete and continuous probability density functions, expectation, jointly distributed random variables, Central Limit Theorem, laws of large numbers. Prerequisite: MACS213, MACS223 or MACS224. 3 hours lecture, 3 semester hours.

MACS335. INTRODUCTION TO MATHEMATICAL STATISTICS (II) An introduction to the theory of statistics essential for problems in science and engineering. Topics include sampling distributions, methods of point estimation, methods of interval estimation, significance testing for population means and variances and goodness of fit, linear regression, analysis of variance. Prerequisite: MACS334 3 hours lecture, 3 semester hours.

MACS340. COOPERATIVE EDUCATION (I, II, S) (WI) Supervised, full-time engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

MACS341. MACHINE ORGANIZATION AND ASSEMBLY LANGUAGE PROGRAMMING (I, II) Covers the basic concepts of computer architecture and organization.

Topics include machine level instructions and operating system calls used to write programs in assembly language. This course provides insight into the way computers operate at the machine level. Prerequisite: MACS261. 3 hours lecture; 3 semester hours.

MACS342. HONORS LINEAR ALGEBRA (II) Same topics as those covered in MACS332 but with additional material and problems as well as a more rigorous presentation. Prerequisite: MACS213, MACS223 or MACS224. 3 hours lecture; 3 semester hours.

MACS348. ADVANCED ENGINEERING MATHEMATICS (I, II, S) Introduction to partial differential equations, with applications to physical phenomena. Fourier series. Linear algebra, with emphasis on sets of simultaneous equations. This course cannot be used as a MACS elective by MACS majors. Prerequisite: MACS315 or MACS325. 3 hours lecture; 3 semester hours.

MACS358. DISCRETE MATHEMATICS & ALGEBRAIC STRUCTURES (I, II) This course is an introductory course in discrete mathematics and algebraic structures. Topics include: formal logic; proofs, recursion, analysis of algorithms; sets and combinatorics; relations, functions, and matrices; Boolean algebra and computer logic; trees, graphs, finite-state machines and regular languages. Prerequisite: MACS213, MACS223 or MACS224. 3 hours lecture; 3 semester hours.

MACS370. FIELD COURSE (S) (WI) This is the Computer Science option's capstone course where the students apply their course work knowledge to a challenging applied problem in mathematics or computer science. In this course they analyze, modify and solve a significant applied problem. The students work in groups of three or four for a period of six forty-hour weeks. By the end of the field session they must have a finished product with appropriate supporting documents. At a minimum CS students should have completed coursework through MACS306 and Mathematics students should have coursework through MACS333 and MACS332 or MACS342. Prerequisite: Consent of Instructor. 6-week summer field session; 6 semester hours.

MACS398. SPECIAL TOPICS (I, II, S) Selected topics chosen from special interests of instructor and students. Prerequisite: Consent of Department Head. 1 to 3 semester hours.

MACS399. INDEPENDENT STUDY (I, II, S) Individual research or special problem projects supervised by a faculty member given agreement on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable Credit: 1 to 6 credit hours.

Senior Year

MACS400. PRINCIPLES OF PROGRAMMING LANGUAGES (I, II) Study of the principles relating to design, evaluation and implementation of programming languages of historical and technical interest, considered as individual entities and with respect to their relationships to other languages.

Topics discussed for each language include: history, design, structural organization, data structures, name structures, control structures, syntactic structures, and implementation of issues. The primary languages discussed are FORTRAN, PASCAL, LISP, ADA, C/C++, JAVA, PROLOG, PERL. Prerequisite: MACS262. 3 hours lecture; 3 semester hours.

MACS401. INTRODUCTION TO ANALYSIS (I) This course is a first course in real analysis that lays out the context and motivation of analysis in terms of the transition from power series to those less predictable series. The course is taught from a historical perspective. It covers an introduction to the real numbers, sequences and series and their convergence, real-valued functions and their continuity and differentiability, sequences of functions and their pointwise and uniform convergence, and Riemann-Stieltjes integration theory. Prerequisite: MACS213, MACS223 or MACS224, and MACS332 or MACS342. 3 hours lecture; 3 semester hours.

MACS403. DATA BASE MANAGEMENT (I) Design and evaluation of information storage and retrieval systems, including defining and building a data base and producing the necessary queries for access to the stored information. Generalized data base management systems, query languages, and data storage facilities. General organization of files including lists, inverted lists and trees. System security and system recovery, and system definition. Interfacing host language to data base systems. Prerequisite: MACS262. 3 hours lecture; 3 semester hours.

MACS404. ARTIFICIAL INTELLIGENCE (I) General investigation of the Artificial Intelligence field. During the first part of the course a working knowledge of the LISP programming language is developed. Several methods used in artificial intelligence such as search strategies, knowledge representation, logic and probabilistic reasoning are developed and applied to problems. Learning is discussed and selected applications presented. Prerequisite: MACS262, MACS358. 3 hours lecture; 3 semester hours.

MACS406. DESIGN AND ANALYSIS OF ALGORITHMS (I, II) Divide-and-conquer: splitting problems into subproblems of a finite number. Greedy: considering each problem piece one at a time for optimality. Dynamic programming: considering a sequence of decisions in problem solution. Searches and traversals: determination of the vertex in the given data set that satisfies a given property. Techniques of backtracking, branch-and-bound techniques, techniques in lower bound theory. Prerequisite: MACS262, MACS213, MACS223 or MACS224, MACS358. 3 hours lecture; 3 semester hours.

MACS407. INTRODUCTION TO SCIENTIFIC COMPUTING (I, II) Round-off error in floating point arithmetic, conditioning and stability, solution techniques (Gaussian elimination, LU factorization, iterative methods) of linear algebraic systems, curve and surface fitting by the method of least-squares, zeros of nonlinear equations and systems by

iterative methods, polynomial interpolation and cubic splines, numerical integration by adaptive quadrature and multivariate quadrature, numerical methods for initial value problems in ordinary differential equations. Emphasis is on problem solving using efficient numerical methods in scientific computing. Prerequisite: MACS315 or MACS325 and knowledge of computer programming. 3 hours lecture; 3 semester hours.

MACS411. INTRODUCTION TO EXPERT SYSTEMS (II) General investigation of the field of expert systems. The first part of the course is devoted to designing expert systems. The last half of the course is implementation of the design and construction of demonstration prototypes of expert systems. Prerequisite: MACS262, MACS358. 3 hours lecture; 3 semester hours.

MACS424. INTRODUCTION TO APPLIED STATISTICS (I) Linear regression, analysis of variance, and design of experiments, focusing on the construction of models and evaluation of their fit. Techniques covered will include stepwise and best subsets regression, variable transformations, and residual analysis. Emphasis will be placed on the analysis of data with statistical software. Prerequisites: MACS323 or MACS335. 3 hours lecture; 3 semester hours.

MACS433/BELS433 MATHEMATICAL BIOLOGY (I) This course will discuss methods for building and solving both continuous and discrete mathematical models. These methods will be applied to population dynamics, epidemic spread, pharmacokinetics and modeling of physiologic systems. Modern Control Theory will be introduced and used to model living systems. Some concepts related to self-organizing systems will be introduced. Prerequisite: MACS315 or MACS325. 3 hours lecture, 3 semester hours.

MACS436. ADVANCED STATISTICAL MODELING (II) Modern methods for constructing and evaluating statistical models. Topics include generalized linear models, generalized additive models, hierarchical Bayes methods, and resampling methods. Prerequisites: MACS335 and MACS424. 3 hours lecture; 3 semester hours.

MACS437. MULTIVARIATE ANALYSIS (II) Introduction to applied multivariate techniques for data analysis. Topics include principal components, cluster analysis, MANOVA and other methods based on the multivariate Gaussian distribution, discriminant analysis, classification with nearest neighbors. Prerequisites: MACS335 or MACS323. 3 hours lecture; 3 semester hours.

MACS438. STOCHASTIC MODELS (II) An introduction to stochastic models applicable to problems in engineering, physical science, economics, and operations research. Markov chains in discrete and continuous time, Poisson processes, and topics in queuing, reliability, and renewal theory. Prerequisite: MACS434. 3 hours lecture, 3 semester hours.

MACS440. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS (I) This course is designed to introduce the field of parallel computing to all scientists and engineers. The students will be taught how to solve scientific problems. They will be introduced to various software and hardware issues related to high performance computing. Prerequisite: Programming experience in C++, consent of instructor. 3 hours lecture; 3 semester hours.

MACS441. COMPUTER GRAPHICS (I) Data structures suitable for the representation of structures, maps, three-dimensional plots. Algorithms required for windowing, color plots, hidden surface and line, perspective drawings. Survey of graphics software and hardware systems. Prerequisite: MACS262. 3 hours lecture, 3 semester hours.

MACS442. OPERATING SYSTEMS (I, II) Covers the basic concepts and functionality of batch, timesharing and single-user operating system components, file systems, processes, protection and scheduling. Representative operating systems are studied in detail. Actual operating system components are programmed on a representative processor. This course provides insight into the internal structure of operating systems; emphasis is on concepts and techniques which are valid for all computers. Prerequisite: MACS262, MACS341. 3 hours lecture; 3 semester hours.

MACS443. ADVANCED PROGRAMMING CONCEPTS USING JAVA. (I, II) This course will quickly review programming constructs using the syntax and semantics of the Java programming language. It will compare the constructs of Java with other languages and discuss program design and implementation. Object oriented programming concepts will be reviewed and applications, applets, servlets, graphical user interfaces, threading, exception handling, JDBC, and networking as implemented in Java will be discussed. The basics of the Java Virtual Machine will be presented. Prerequisites: MACS261, MACS262. 3 hours lecture, 3 semester hours

MACS445. WEB PROGRAMMING (II) Web Programming is a course for programmers who want to develop Web-based applications. It covers basic web site design extended by client-side and server-side programming. Students should know the elements of HTML and Web architecture and be able to program in a high level language such as C++ or Java. The course builds on this knowledge by presenting topics such as Cascading Style Sheets, JavaScript, PERL and database connectivity that will allow the students to develop dynamic Web applications. Prerequisites: Fluency in a high level computer language/consent of instructor. 3 hours lecture, 3 semester hours.

MACS454. COMPLEX ANALYSIS (II) The complex plane. Analytic functions, harmonic functions. Mapping by elementary functions. Complex integration, power series, calculus of residues. Conformal mapping. Prerequisite: MACS315 or MACS325. 3 hours lecture, 3 semester hours.

MACS455. PARTIAL DIFFERENTIAL EQUATIONS (I) Linear partial differential equations, with emphasis on the classical second-order equations: wave equation, heat equation, Laplace's equation. Separation of variables, Fourier methods, Sturm-Liouville problems. Prerequisite: MACS315 or MASCS325. 3 hours lecture; 3 semester hours.

MACS461. SENIOR SEMINAR I (I) (WI) Students present topics orally and write research papers using undergraduate mathematical and computer sciences techniques, emphasizing critical analysis of assumptions and models. Prerequisite: Consent of Department. 1 hour seminar; 1 semester hour.

MACS462. SENIOR SEMINAR II (II) (WI) Students present topics orally and write research papers using undergraduate mathematical and computer sciences techniques, emphasizing critical analysis of assumptions and models. Prerequisite: Consent of Department. 1 hour seminar; 1 semester hour.

MACS471. COMPUTER NETWORKS I (I) This introduction to computer networks covers the fundamentals of computer communications, using TCP/IP standardized protocols as the main case study. The application layer and transport layer of communication protocols will be covered in depth. Detailed topics include application layer protocols (HTTP, FTP, SMTP, and DNS), reliable data transfer, connection management, and congestion control. In addition, students will build a computer network from scratch and program client/server network applications. Prerequisite: MACS442 or consent of instructor. 3 hours lecture, 3 semester hours.

MACS491. UNDERGRADUATE RESEARCH (I) (WI) Individual investigation under the direction of a department faculty member. Written report required for credit. Prerequisite: Consent of Department Head. 1 to 3 semester hours, no more than 6 in a degree program.

MACS492. UNDERGRADUATE RESEARCH (II) (WI) Individual investigation under the direction of a department faculty member. Written report required for credit. Prerequisite: Consent of Department Head. 1 to 3 semester hours, no more than 6 in a degree program.

MACS498. SPECIAL TOPICS (I, II, S) Selected topics chosen from special interests of instructor and students. Prerequisite: Consent of Department Head. 1 to 3 semester hours.

MACS499. INDEPENDENT STUDY (I, II, S) Individual research or special problem projects supervised by a faculty member; also, given agreement on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable Credit: 1 to 6 credit hours.

Metallurgical and Materials Engineering

JOHN J. MOORE, Trustees Professor and Department Head
STEPHEN LIU, Professor
GERARD P. MARTINS, Professor
DAVID K. MATLOCK, Charles S. Fogarty Professor
BRAJENDRA MISHRA, Professor
DAVID L. OLSON, John H. Moore Distinguished Professor
IVAR E. REIMANIS, Professor
JOHN G. SPEER, Professor
PATRICK R. TAYLOR, George S. Ansell Distinguished Professor of
Chemical Metallurgy
CHESTER J. VAN TYNE, FIERF Professor
STEVEN W. THOMPSON, Associate Professor
PATRICIO MENDEZ, Assistant Professor
RYAN P. O'HAYRE, Assistant Professor
EDGAR E. VIDAL, Assistant Professor
JOHN P. CHANDLER, Lecturer
MARTIN C. MATAYA, Lecturer
GEORGE S. ANSELL, President Emeritus and Professor Emeritus
W. REX BULL, Professor Emeritus
GERALD L. DePOORTER, Associate Professor Emeritus
GLEN R. EDWARDS, University Professor Emeritus
ROBERT H. FROST, Associate Professor Emeritus
JOHN P. HAGES, University Professor Emeritus
GEORGE KRAUSS, University Professor Emeritus
DENNIS W. READEY, Herman F. Coors Distinguished Professor
Emeritus

Program Description

Metallurgical and materials engineering plays a role in all manufacturing processes which convert raw materials into useful products adapted to human needs. The primary outcome of the Metallurgical and Materials Engineering program is to provide undergraduates with a fundamental knowledge-base associated with materials—processing, their properties, and their selection and application. Upon graduation, students would have acquired and developed the necessary background and skills for successful careers in the materials-related industries. Furthermore, the benefits of continued education toward graduate degrees and other avenues, and the pursuit of knowledge in other disciplines should be well inculcated.

The emphasis in the Department is on materials processing operations which encompass: the conversion of mineral and chemical resources into metallic, ceramic or polymeric materials; the synthesis of new materials; refining and processing to produce high performance materials for applications from consumer products to aerospace and electronics, the development of mechanical, chemical and physical properties of materials related to their processing and structure, the selection of materials for specific applications.

The metallurgical and materials engineering discipline is founded on fundamentals in chemistry, mathematics and

physics which contribute to building the knowledge-base and developing the skills for the processing of materials so as to achieve specifications requested for a particular industrial or advanced product. The engineering principles in this discipline include: crystal structure and structural analysis, thermodynamics of materials, reaction kinetics, transport phenomena, phase equilibria, phase transformations, microstructural evolution and properties of materials.

The core-discipline fundamentals are applied to a broad range of materials processes including extraction and refining of materials, alloy development, casting, mechanical working, joining and forming, ceramic particle processing, high temperature reactions and synthesis of engineered materials. In each stage of processing, the effects of resultant microstructures and morphologies on materials properties and performance are emphasized.

Laboratories, located in Nathaniel Hill Hall, are among the best in the nation. The laboratories, in conjunction with classroom instruction, provide for a well integrated education of the undergraduates working towards their baccalaureate degrees. These facilities are well-equipped and dedicated to: particulate and chemical/extraction metallurgical-and-materials processing, foundry science, corrosion and hydro-/electro-metallurgical studies, physical and mechanical metallurgy, welding and joining, forming and processing-and-testing of ceramic materials. Mechanical testing facilities include computerized machines for tensile, compression, torsion, toughness, fatigue and thermo-mechanical testing. There are also other highly specialized research laboratories dedicated to: robotics, artificial intelligence, vapor deposition, and plasma and high-temperature reaction-systems. Support analytical-laboratories for surface analysis, emission spectrometry, X-ray analysis, optical microscopy and image analysis, electron microscopy, including an analytical scanning transmission electron microscopy and the latest in scanning electron microscopy, and micro-thermal-analysis/mass spectrometry. Metallurgical and Materials Engineering involves all of the processes which transform precursor materials into final engineered products adapted to human needs. The objective of the Metallurgical and Materials Engineering program is to impart a fundamental knowledge of materials processing, properties, selection and application in order to provide graduates with the background and skills needed for successful careers in materials related industries, for continued education toward graduate degrees and for the pursuit of knowledge in other disciplines.

The program leading to the degree Bachelor of Science in Metallurgical and Materials Engineering is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Metallurgical and Materials Engineering (MME) Program Educational Objectives

The Metallurgical and Materials Engineering (MME) program emphasizes the structure, properties, processing and performance of materials and, as such, is designed to support five primary educational objectives that will be demonstrated by recent graduates of the program.

The MME program is designed and implemented so as to develop graduates who:

1. Have a broad knowledge base of materials engineering fundamentals.
2. Can apply fundamental materials-concepts to solve problems.
3. Have written and oral communication skills as well as teamwork skills to be successful in their careers
4. Understand the importance for self-acquisition of knowledge and continuing education.
5. Can employ their breadth of knowledge so that they are able to provide a range of solutions to a wide range of materials-engineering problems, and ultimately an optimal choice.

The five MME program educational objectives were determined by using inputs from program constituencies (faculty, students, visiting committee, industry/recruiters, alumni). The MME program educational objectives are consistent with those of Colorado School of Mines (CSM). CSM is a school of engineering and applied science institution, dedicated to the education and training of students who will be stewards of the earth's resources.

Curriculum

The Metallurgical and Materials Engineering (MME) curriculum is organized to provide three educational components: fundamentals of materials, applications of the fundamentals, and emphasis in one of three focus areas.

A. MME Basics: The basic curriculum in the Metallurgical and Materials Engineering Department will provide a background in the following topic areas:

1. Crystal Structures and Structural Analysis: Crystal systems; symmetry elements and Miller indices; atomic bonding; metallic, ceramic and polymeric structures; x-ray and electron diffraction; stereographic projection and crystal orientation; long range order; defects in materials.
2. Thermodynamics of Materials: Heat and mass balances; thermodynamic laws; chemical potential and chemical equilibrium; solution thermodynamics & solution models; partial molar and excess quantities; solid state thermodynamics; thermodynamics of surfaces; electrochemistry.
3. Transport Phenomena and Kinetics: Heat, mass and momentum transport; transport properties of fluids; diffusion mechanisms; reaction kinetics; nucleation and growth kinetics.

4. Phase Equilibria: Phase rule; binary and ternary systems; microstructural evolution; defects in crystals; surface phenomena; phase transformations: eutectic, eutectoid, martensitic, nucleation and growth, recovery; microstructural evolution; strengthening mechanisms; quantitative stereology; heat treatment.
5. Properties of Materials: Mechanical properties, chemical properties (oxidation and corrosion); electrical, magnetic and optical properties: failure analysis.

B. MME Applications: The course content in the Metallurgical and Materials Engineering Program emphasizes the following applications:

1. Materials Processing: Particulate processing, thermo- and electro-chemical materials-processing, hydrometallurgical processing, synthesis of materials, deformation processing, casting and welding.
2. Design and Application of Materials: Materials selection, ferrous and nonferrous metals, ceramic materials, polymeric materials, composite materials and electronic materials.
3. Statistical Process Control and Design of Experiments: Statistical process-control, process capability- analysis and design of experiments.

C. MME Focus Areas: There are three Focus Areas within the Metallurgical and Materials Engineering curriculum. These are

1. Physicochemical Processing of Materials
2. Physical Metallurgy
3. Materials Engineering

D. MME Curriculum Requirements: The Metallurgical and Materials Engineering course sequence is designed to fulfill the program goals and to satisfy the curriculum requirements. The time sequence of courses organized by degree program, year and semester, is listed below.

Degree Requirements (Metallurgical and Materials Engineering)

	lec.	lab.	sem.hrs.
Sophomore Year Fall Semester			
DCGN209 Introduction to Thermodynamics	3		3
MACS213 Calculus for Scientists & Engr's III	4		4
PHGN200 Physics II	3.5	3	4.5
SYGN202 Engineered Materials Systems	3		3
PAGN201 Physical Education III		2	0.5
Total			15
Sophomore Year Spring Semester			
MACS315 Differential Equations	3		3
PHGN300 Modern Physics	3		3
DCGN241 Statics	3		3
EPIC251 Design II	2	3	3
EBGN201 Principles of Economics	3		3
SYGN200 Human Systems	3		3
PAGN202 Physical Education IV		2	0.5
Total			18.5

	lec.	lab.	sem.hrs.
Summer Field Session			
MTGN272 Particulate Materials Processing			3
Total			3
Junior Year Fall Semester			
MTGN311 Structure of Materials	3	3	4
MTGN381 Phase Equilibria	2		2
MTGN351 Metallurgical & Materials Thermodynamics	4		4
EGGN320 Mechanics of Materials	3		3
LAIS/EBGN H&SS Cluster Elective I	3		3
Total			16
Junior Year Spring Semester			
MTGN334 Chemical Processing of Materials	3		3
MTGN348 Microstructural Develop. of Materials	3	3	4
MTGN352 Metallurgical & Materials Kinetics	3		3
LAIS/EBGN H&SS Cluster Elective II	3		3
Free Elective	3		3
Total			16
Senior Year Fall Semester			
MTGN445 Mechanical Behavior of Materials	3	3	4
MTGN461 Trans. Phen. & Reactor Design for Met. & Mat. Engs.	2	3	3
MTGN450 Stat Process Control & Design of Experiments	3		3
MTGN—MTGN Elective	3		3
LAIS/EBGN H&SS Cluster Elective III	3		3
Free Elective	3		3
Total			19
Senior Year Spring Semester			
MTGN466 Design, Selection & Use of Mats	1	6	3
MTGN415 Electronic Properties & Applications of Materials			
or			
MTGN442 Engineering Alloys	3		3
MTGN—MTGN Elective	3		3
MTGN—MTGN Elective	3		3
DCGN381 Electric Circuits, Electronics & Power	3		3
Free Elective	3		3
Total			18
Degree Total			138.5

Five Year Combined Metallurgical and Materials Engineering Baccalaureate and Master of Engineering in Metallurgical and Materials Engineering, with an Electronic-Materials Emphasis.#

The Departments of Metallurgical and Materials Engineering and Physics collaborate to offer a five-year program designed to meet the needs of the electronics and similar high-tech industries. Students who satisfy the requirements of the program obtain an undergraduate degree in either Engineering Physics or in Metallurgical and Materials Engineering in four years and a Master of Engineering degree in Metallurgical and Materials Engineering at the end of the fifth year. The program is designed to provide for a strong background in science fundamentals, as well as specialized

training in the materials-science and processing needs of these industries. Thus, the educational objective of the program is to provide students with the specific educational requirements to begin a career in microelectronics and, at the same time, a broad and flexible background necessary to remain competitive in this exciting and rapidly changing industry. The undergraduate electives which satisfy the requirements of the program and an overall curriculum are outlined in an informational package "Enhanced Program for Preparation for Microelectronics," available from either the Physics or Metallurgical and Materials Engineering Departments. A Program Mentor in each Department can also provide counseling on the program.

Application for admission to this program should be made during the first semester of the sophomore year (in special cases, later entry may be approved, upon review, by one of the program mentors). Undergraduate students admitted to the program must maintain a 3.0 grade-point average or better. The graduate segment of the program requires a case study report, submitted to the student's graduate advisor. Additional details on the Master of Engineering can be found in the Graduate Degree and Requirements section of the *Graduate Bulletin*. The case study is started during the student's senior design-project and completed during the year of graduate study. A student admitted to the program is expected to select a graduate advisor, in advance of the graduate-studies final year, and prior to the start of their senior year. The case-study topic is then identified and selected in consultation with the graduate advisor. A formal application, during the senior year, for admission to the graduate program in Metallurgical and Materials Engineering must be submitted to the Graduate School. Students who have maintained all the standards of the program requirements leading up to this step, can expect to be admitted.

#Additional "Emphasis" areas are being developed in conjunction with other Departments on Campus.

Description of Courses

Freshman Year

MTGN198. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: Instructor consent. 1 to 3 semester hours.

MTGN199. INDEPENDENT STUDY (I, II) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic with consent of faculty supervisor; "Independent Study Form" must be completed and submitted to Registrar. 1 to 3 semester hours.

Sophomore Year

MTGN272. PARTICULATE MATERIALS PROCESSING (S) Field session. Characterization and production of particles. Physical and interfacial phenomena associated with particulate processes. Applications to metal and ceramic powder processing. Laboratory projects and plant visits. Prerequisites: DCGN209 and PHGN200. 3 weeks; 3 semester hours.

MTGN298. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: Consent of Instructor. 1 to 3 semester hours.

MTGN299. INDEPENDENT STUDY (I, II) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic with consent of faculty supervisor; "Independent Study Form" must be completed and submitted to Registrar. 1 to 3 semester hours.

Junior Year

MTGN300. FOUNDRY METALLURGY (II) Design and metallurgical aspects of casting, patterns, molding materials and processes, solidification processes, risering and gating concepts, casting defects and inspection, melting practice, cast alloy selection. Prerequisite: PHGN200/210. Co-requisite: MTGN302 or Consent of Instructor. 2 hours lecture; 2 semester hours.

MTGN301. MATERIALS ENGINEERING DESIGN AND MAINTENANCE (I) Introduction of the necessary metallurgical concepts for effective mine maintenance. Topics to include steel selection, heat treatment, mechanical properties, casting design and alloys, casting defects, welding materials and processes selection, weld defects, weld design, forms of corrosion protection, stainless steel, mechanical forming, aluminum and copper alloy systems, and metal failure identification. This course is designed for students from outside the Metallurgical and Materials Engineering Department. Prerequisite: Consent of Instructor. 3 hours lecture; 3 semester hours.

MTGN302. FOUNDRY METALLURGY LABORATORY (II) Experiments in the foundry designed to supplement the lectures of MTGN300. Co-requisite: MTGN300. 3 hours lab; 1 semester hour.

MTGN311. STRUCTURE OF MATERIALS (I) (WI) Principles of crystallography and crystal chemistry. Characterization of crystalline materials using X-ray diffraction techniques. Applications to include compound identification, lattice parameter measurement, orientation of single crystals, and crystal structure determination. Laboratory experiments to supplement the lectures. Prerequisites: PHGN200/210 and SYGN202. 3 hours lecture, 3 hours lab; 4 semester hours.

MTGN334. CHEMICAL PROCESSING OF MATERIALS (II) Development and application of fundamental principles related to the processing of metals and materials by thermochemical and aqueous and fused salt electrochemical/chemical routes. The course material is presented within the framework of a formalism that examines the physical chemistry, thermodynamics, reaction mechanisms and kinetics inherent to a wide selection of chemical-processing systems. This general formalism provides for a transferable knowledge-base to other systems not specifically covered in the course. Prerequisite: MTGN272 and MTGN351. 3 hours lecture; 3 semester hours.

MTGN340. COOPERATIVE EDUCATION (I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second-semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

MTGN348. MICROSTRUCTURAL DEVELOPMENT (II) (WI) Introduction to the relationships between microstructure and properties of materials, with emphasis on metals. Fundamentals of imperfections in crystalline materials, phase equilibria, recrystallization and grain growth, strengthening mechanisms, and phase transformations. Laboratory sessions devoted to experiments illustrating the fundamentals presented in the lectures. Prerequisites: MTGN311 and MTGN351. 3 hours lecture, 3 hours lab; 4 semester hours.

MTGN351. METALLURGICAL AND MATERIALS THERMODYNAMICS (I) Applications of thermodynamics in extractive and physical metallurgy and materials science. Thermodynamics of solutions including solution models, calculation of activities from phase diagrams, and measurements of thermodynamic properties of alloys and slags. Reaction equilibria with examples in alloy systems and slags. Phase stability analysis. Thermodynamic principles of phase diagrams in material systems, defect equilibrium and interactions. Prerequisite: DCGN209. 4 hours lecture; 4 semester hours.

MTGN352. METALLURGICAL AND MATERIALS KINETICS (II) Introduction to reaction kinetics: chemical kinetics, atomic and molecular diffusion, surface thermodynamics and kinetics of interfaces and nucleation-and-growth. Applications to materials processing and performance aspects associated with gas/solid reactions, precipitation and dissolution behavior, oxidation and corrosion, purification of semiconductors, carburizing of steel, formation of p-n junctions and other important materials systems. Prerequisite: MTGN351. 3 hours lecture; 3 semester hours.

MTGN381. INTRODUCTION TO PHASE EQUILIBRIA IN MATERIALS SYSTEMS (I) Review of the concepts of chemical equilibrium and derivation of the Gibbs Phase

Rule. Application of the Gibbs Phase Rule to interpreting one, two and three component Phase Equilibrium Diagrams. Application to alloy and ceramic materials systems. Emphasis on the evolution of phases and their amounts and the resulting microstructural development. Prerequisite/ Co-requisite: MTGN351. 2 hours lecture; 2 semester hours.

MTGN390/EGGN390. MATERIALS AND MANUFACTURING PROCESSES (I, II, S) Engineering materials and the manufacturing processes used in their conversion into a product or structure as critical considerations in design. Properties, characteristics, typical selection criteria, and applications are reviewed for ferrous and nonferrous metals, plastics and composites. Characteristics, features, and economics of basic shaping operations are addressed with regard to their limitations and applications and the types of processing equipment available. Related technology such as measurement and inspection procedures, numerical control systems and automated operations are introduced concomitantly. Prerequisite: EGGN320 and SYGN202 or Consent of Instructor. 3 hours lecture; 3 semester hours.

MTGN398. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: Consent of Instructor. 1 to 3 semester hours.

MTGN399. INDEPENDENT STUDY (I, II) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic with consent of faculty supervisor; "Independent Study Form" must be completed and submitted to Registrar. 1 to 3 semester hours.

Senior Year

MTGN403. SENIOR THESIS (I, II) Two semester individual research under the direction of members of the Metallurgical and Materials Engineering faculty. Work may include library and laboratory research on topics of relevance. Oral presentation will be given at the end of the second semester and written thesis submitted to the committee for evaluation. Prerequisites: Senior standing in the Department of Metallurgical and Materials Engineering and Consent of Department Head. 6 semester hours (3 hours per semester).

MTGN412/MLGN512. CERAMIC ENGINEERING (I) Application of engineering principles to nonmetallic and ceramic materials. Processing of raw materials and production of ceramic bodies, glazes, glasses, enamels, and cements. Firing processes and reactions in glass bonded as well as mechanically bonded systems. Prerequisite: MTGN348. 3 hours lecture; 3 semester hours.

MTGN414/MLGN544. PROCESSING OF CERAMICS (II) Principles of ceramic processing and the relationship between processing and microstructure. Raw materials and raw materials preparation, forming and fabrication, thermal processing, and finishing of ceramic materials will be covered. Principles will be illustrated by case studies on specific ceramic materials. A project to design a ceramic fabrication process is required. Field trips to local ceramic manufacturing operations. Prerequisite: MTGN31 or consent of the instructor. 3 hours lecture; 3 semester hours.

MTGN415/MLGN515. ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS (II) Survey of the electrical properties of materials, and the applications of materials as electrical circuit components. The effects of chemistry, processing and microstructure on the electrical properties. Functions, performance requirements and testing methods of materials for each type of circuit component. General topics covered are conductors, resistors, insulators, capacitors, energy converters, magnetic materials and integrated circuits. Prerequisites: PHGN200, MTGN311 or MLGN501, or consent of instructor. 3 hours lecture; 3 semester hours.

MTGN416/MLGN516. PROPERTIES OF CERAMICS (II) Survey of the properties of ceramic materials and how these properties are determined by the chemical structure (composition), crystal structure, and the microstructure of crystalline ceramics and glasses. Thermal, optical, and mechanical properties of single-phase and multiphase ceramics, including composites, are covered. Prerequisites: PHGN200, MTGN311 or MLGN501, MTGN412 or Consent of Instructor. 3 hours lecture, 3 semester hours.

MTGN417. REFRACTORY MATERIALS (I) Refractory materials in metallurgical construction. Oxide phase diagrams for analyzing the behavior of metallurgical slags in contact with materials of construction. Prerequisite: Consent of Instructor. 3 hours lecture; 3 semester hours.

MTGN419/MLGN519. NON-CRYSTALLINE MATERIALS (II) Introduction to the principles of glass science-and-engineering and non-crystalline materials in general. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisites: MTGN311 or MLGN501, MLGN512/MTGN412, or Consent of Instructor. 3 hours lecture; 3 semester hours.

MTGN422. PROCESS ANALYSIS AND DEVELOPMENT (II) Aspects of process development, plant design and management. Prerequisite: MTGN334. Co-requisite: MTGN424 or Consent of Instructor. 2 hours lecture; 2 semester hours.

MTGN424. PROCESS ANALYSIS AND DEVELOPMENT LABORATORY (II) Projects to accompany the lectures in MTGN422. Prerequisite: MTGN422 or Consent of Instructor. 3 hours lab; 1 semester hour.

MTGN430. PHYSICAL CHEMISTRY OF IRON AND STEELMAKING (I) Physical chemistry principles of blast furnace and direct reduction production of iron and refining of iron to steel. Discussion of raw materials, productivity, impurity removal, deoxidation, alloy additions, and ladle metallurgy. Prerequisite: MTGN334. 3 hours lecture; 3 semester hours.

MTGN431. HYDRO- AND ELECTRO-METALLURGY (I) Physicochemical principles associated with the extraction and refining of metals by hydro- and electrometallurgical techniques. Discussion of unit processes in hydrometallurgy, electrowinning, and electrorefining. Analysis of integrated flowsheets for the recovery of nonferrous metals. Prerequisites: MTGN334, MTGN351 and MTGN352. Co-requisite: MTGN461, MTGN433 or Consent of Instructor. 2 hours lecture; 2 semester hours.

MTGN432. PYROMETALLURGY (II) Extraction and refining of metals including emerging practices. Modifications driven by environmental regulations and by energy minimization. Analysis and design of processes and the impact of economic constraints. Prerequisite: MTGN334. 3 hours lecture; 3 semester hours.

MTGN433. HYDRO- AND ELECTRO-METALLURGY LABORATORY (I) Experiments designed to supplement the lectures in MTGN431. Co-requisite: MTGN431 or Consent of Instructor. 3 hours lab; 1 semester hours.

MTGN434. DESIGN AND ECONOMICS OF METALLURGICAL PLANTS (II) Design of metallurgical processing systems. Methods for estimating process costs and profitability. Performance, selection, and design of process equipment. Integration of process units into a working plant and its economics, construction, and operation. Market research and surveys. Prerequisites: DCGN209, MTGN351 or Consent of Instructor. 3 hours lecture; 3 semester hours.

MTGN436. CONTROL AND INSTRUMENTATION OF METALLURGICAL PROCESSES (II) Analysis of processes for metal extraction and refining using classical and direct-search optimization methods and classical process control with the aid of chemical functions and thermodynamic transfer operations. Examples from processes in physicochemical and physical metallurgy. Prerequisite: MTGN334 or Consent of Instructor. Co-requisite: MTGN438 or Consent of Instructor. 2 hours lecture; 2 semester hours.

MTGN438. CONTROL AND INSTRUMENTATION OF METALLURGICAL PROCESSES LABORATORY (II) Experiments designed to supplement the lectures in MTGN436. Prerequisite: MTGN436 or Consent of Instructor. 3 hours lab; 1 semester hour.

MTGN442. ENGINEERING ALLOYS (II) This course is intended to be an important component of the physical metallurgy sequence, to reinforce and integrate principles from earlier courses, and enhance the breadth and depth of under-

standing of concepts in a wide variety of alloy systems. Metallic systems considered include iron and steels, copper, aluminum, titanium, superalloys, etc. Phase stability, microstructural evolution and structure/property relationships are emphasized. Prerequisite: MTGN348 or Consent of Instructor. 3 hours lecture; 3 semester hours.

MTGN445/MLGN505*. MECHANICAL PROPERTIES OF MATERIALS (I) (WI) Mechanical properties and relationships. Plastic deformation of crystalline materials. Relationships of microstructures to mechanical strength. Fracture, creep, and fatigue. Laboratory sessions devoted to advanced mechanical-testing techniques to illustrate the application of the fundamentals presented in the lectures. Prerequisite: MTGN348. 3 hours lecture, 3 hours lab; 4/3* semester hours. *This is a 3 semester-hours graduate-course in the Materials Science Program (ML) and a 4 semester-hours undergraduate-course in the MTGN program.

MTGN450/MLGN550. STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS (I) Introduction to statistical process control, process capability analysis and experimental design techniques. Statistical process control theory and techniques developed and applied to control charts for variables and attributes involved in process control and evaluation. Process capability concepts developed and applied to the evaluation of manufacturing processes. Theory of designed experiments developed and applied to full factorial experiments, fractional factorial experiments, screening experiments, multilevel experiments and mixture experiments. Analysis of designed experiments by graphical and statistical techniques. Introduction to computer software for statistical process control and for the design and analysis of experiments. Prerequisite: Consent of Instructor. 3 hours lecture, 3 semester hours.

MTGN451. CORROSION ENGINEERING (II) Principles of electrochemistry. Corrosion mechanisms. Methods of corrosion control including cathodic and anodic protection and coatings. Examples, from various industries, of corrosion problems and solutions. Prerequisite: DCGN209. 3 hours lecture; 3 semester hours

MTGN452. CERAMIC AND METAL MATRIX COMPOSITES Introduction to the synthesis, processing, structure, properties and performance of ceramic and metal matrix composites. Survey of various types of composites, and correlation between processing, structural architecture and properties. Prerequisites: MTGN272, MTGN311, MTGN348, MTGN351. 3 hours lecture; 3 semester hours

MTGN453. PRINCIPLES OF INTEGRATED CIRCUIT PROCESSING (I) Introduction to the electrical conductivity of semiconductor materials; qualitative discussion of active semiconductor devices; discussion of the steps in integrated circuit fabrication; detailed investigation of the materials science and engineering principles involved in the various steps

of VLSI device fabrication; a presentation of device packaging techniques and the processes and principles involved. Prerequisite: Consent of Instructor. 3 hours lecture; 3 semester hours.

MTGN456. ELECTRON MICROSCOPY (II) Introduction to electron optics and the design and application of transmission and scanning electron microscopes. Interpretation of images produced by various contrast mechanisms. Electron diffraction analysis and the indexing of electron diffraction patterns. Prerequisite: MTGN311 or Consent of Instructor. Co-requisite: MTGN458. 2 hours lecture; 2 semester hours.

MTGN458. ELECTRON MICROSCOPY LABORATORY (II) Laboratory exercises to illustrate specimen preparation techniques, microscope operation, and the interpretation of images produced from a variety of specimens, and to supplement the lectures in MTGN456. Co-requisite: MTGN456. 3 hours lab; 1 semester hour.

MTGN461. TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL-AND-MATERIALS ENGINEERS (I) Introduction to the conserved-quantities: momentum, heat, and mass transfer, and application of chemical kinetics to elementary reactor-design. Examples from materials processing and process metallurgy. Molecular transport properties: viscosity, thermal conductivity, and mass diffusivity of materials encountered during processing operations. Uni-directional transport: problem formulation based on the required balance of the conserved- quantity applied to a control-volume. Prediction of velocity, temperature and concentration profiles. Equations of change: continuity, motion, and energy. Transport with two independent variables (unsteady-state behavior). Interphase transport: dimensionless correlations friction factor, heat, and mass transfer coefficients. Elementary concepts of radiation heat-transfer. Flow behavior in packed beds. Design equations for: Continuous- Flow/ Batch Reactors with Uniform Dispersion and Plug Flow Reactors. Digital computer methods for the design of metallurgical systems. Laboratory sessions devoted to: Tutorials/ Demonstrations to facilitate the understanding of concepts related to selected topics; and, Projects with the primary focus on the operating principles and use of modern electronic-instrumentation for measurements on lab-scale systems in conjunction with correlation and prediction strategies for analysis of results. Prerequisites: MACS315, MTGN334 and MTGN352. 2 hours lecture, 3 hours lab; 3 semester hours.

MTGN462/ESGN462. SOLID WASTE MINIMIZATION AND RECYCLING (I) This course will examine, using case studies, how industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisites: EGGN/ESGN353, EGGN/ESGN354, and ESGN302/CHGN403 or Consent of Instructor. 3 hours lecture; 3 semester hours.

MTGN463. POLYMER ENGINEERING (I) Introduction to the structure and properties of polymeric materials, their deformation and failure mechanisms, and the design and fabrication of polymeric end items. Molecular and crystallographic structures of polymers will be developed and related to the elastic, viscoelastic, yield and fracture properties of polymeric solids and reinforced polymer composites. Emphasis on forming and joining techniques for end-item fabrication including: extrusion, injection molding, reaction injection molding, thermoforming, and blow molding. The design of end-items in relation to: materials selection, manufacturing engineering, properties, and applications. Prerequisite: Consent of Instructor. 3 hours lecture; 3 semester hours.

MTGN464. FORGING AND FORMING (II) Introduction to plasticity. Survey and analysis of working operations of forging, extrusion, rolling, wire drawing and sheet-metal forming. Metallurgical structure evolution during working. Prerequisites: EGGN320 and MTGN348 or EGGN390. 2 hours lecture; 3 hours lab, 3 semester hours

MTGN466. MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION (II) (WI) Application of fundamental materials-engineering principles to the design of systems for extraction and synthesis, and to the selection of materials. Systems covered range from those used for metallurgical processing to those used for processing of emergent materials. Microstructural design, characterization and properties evaluation provide the basis for linking synthesis to applications. Selection criteria tied to specific requirements such as corrosion resistance, wear and abrasion resistance, high temperature service, cryogenic service, vacuum systems, automotive systems, electronic and optical systems, high strength/weight ratios, recycling, economics and safety issues. Materials investigated include mature and emergent metallic, ceramic and composite systems used in the manufacturing and fabrication industries. Student-team design-activities including oral- and written-reports. Prerequisite: MTGN351, MTGN352, MTGN445 and MTGN461 or Consent of Instructor. 1 hour lecture, 6 hours lab; 3 semester hours.

MTGN475. METALLURGY OF WELDING (I) Introduction to welding processes thermal aspects; metallurgical evaluation of resulting microstructures; attendant phase transformations; selection of filler metals; stresses; stress relief and annealing; preheating and post heating; distortion and defects; welding ferrous and nonferrous alloys; and, welding tests. Prerequisite: MTGN348. Co-requisite: MTGN477. 2 hours lecture; 2 semester hours.

MTGN477. METALLURGY OF WELDING LABORATORY (I) Experiments designed to supplement the lectures in MTGN475. Prerequisite: MTGN475. 3 hours lab; 1 semester hour.

MTGN498. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: Consent of Instructor. 1 to 3 semester hours.

MTGN499. INDEPENDENT STUDY (I, II) Independent advanced-work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Selection of problem is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic with consent of faculty supervisor; "Independent Study Form" must be completed and submitted to Registrar. 1 to 3 semester hours.

Mining Engineering

TIBOR G. ROZGONYI, Professor and Department Head
KADRI DAGDELEN, Professor
UGUR OZBAY, Professor
LEVENT OZDEMIR, Professor and Director of Earth Mechanics Institute
MARK KUCHTA, Associate Professor
HUGH MILLER, Associate Professor
MASAMI NAKAGAWA, Associate Professor
D. SCOTT KIEFFER, Assistant Professor
MANOHAR ARORA, Senior Lecturer
BAKI YARRAR, Professor Emeritus
VILEM PETR, Research Assistant Professor

Program Description

Mining engineering is a broad profession, which embraces all required activities to facilitate the recovery of valuable minerals and products from the earth's crust for the benefit of humanity. It is one of the oldest engineering professions, which continues to grow in importance. It has often been said: "If it was not grown in the field or fished out of the water, then it must have been mined." An adequate supply of mineral products at competitive prices is the life-blood of the continuing growth of industrialized nations and the foundation of the progress for the developing countries.

The function of the mining engineer is to apply knowledge of pertinent scientific theory, engineering fundamentals, and improved technology to recover natural resources. Mining is a world-wide activity involving the extraction of non-metallics, metal ores of all kinds, and solid fuel and energy sources such as coal and nuclear materials. In addition to mineral extraction, the skills of mining engineers are also needed in a variety of fields where the earth's crust is utilized, such as the underground construction industry. The construction industry, with its requirements of developing earth (rock) systems, tunnels and underground chambers, and the hazardous waste disposal industry are examples of such applications. These are expanding needs, with a shortage of competent people; the mining engineer is well qualified to meet these needs.

The importance of ecological and environmental planning is recognized and given significant attention in all aspects of the mining engineering curriculum.

CSM mining engineering students study the principles and techniques of mineral exploration, and underground and surface mining operations, as well as, mineral processing technologies. Studies include rock mechanics, rock fragmentation, plant and mine design, mine ventilation, surveying, valuation, industrial hygiene, mineral law, mine safety, computing, mineral processing, solution mining and operations research. Throughout the mining engineering curriculum, a constant effort is made to maintain a balance between theoretical principles and their engineering applications. The mining engineering graduate is qualified for positions in engineering, supervision, and research.

The program leading to the degree Bachelor of Science in Mining Engineering is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Program Educational Objectives (Bachelor of Science in Mining Engineering)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate profile and the ABET Accreditation Criteria, the educational objectives which the Mining Engineering Department aspires to accomplish can be seen in the attributes of our graduates. The graduate is equipped with:

- ◆ A sound knowledge in the required basic sciences and engineering fundamentals;
- ◆ Knowledge and experience in the application of engineering principles to the exploitation of earth's resources and construction of earth (rock) systems in an engineering systems orientation and setting;
- ◆ Ability to solve complex mining and earth systems related problems;
- ◆ Capability for team work and decision making;
- ◆ Appreciation of the global role of minerals in the changing world;
- ◆ Desire for continuing education, intellectual and professional development, analysis and creativity;
- ◆ Self confidence and articulation, with high professional and ethical standards.

Curriculum

The mining engineering curriculum is devised to facilitate the widest employability of CSM graduates. The curriculum is based on scientific engineering and geologic fundamentals and the application of these fundamentals to design and operate mines and to create structures in rock and prepare mine products for the market. To achieve this goal, the curriculum is designed to ensure that the graduates:

- ◆ become broad based mining engineers who can tackle the problems of both hard and soft rock mining, regardless of whether the mineral deposit requires surface or underground methods of extraction,
- ◆ have an opportunity, through elective courses, to specialize in one or more aspects of the mining engineering profession,
- ◆ are interested in an academic or research career, or wish to pursue employment in related fields, have a sufficiently sound scientific and engineering foundation to do so effectively.

This purpose permeates both the lower and upper division courses. Another important aspect of the curriculum is the development of the students' capabilities to be team members, with the added objective of preparing them for leader-

ship in their professional life. The curriculum focuses on the application of engineering principles to solving problems, in short, engineering design in an earth systems approach.

Degree Requirements (Mining Engineering)

	lec.	lab.	sem.hrs.
Sophomore Year Fall Semester			
MACS213 Calc. for Scientists & Engr's III	4		4
PHGN200 Physics II	3.5	3	4.5
EBGN201 Principles of Economics	3		3
DCGN241 Statics	3		3
EPIC251 Design II	2	3	3
PAGN201 Physical Education III		2	0.5
Total			18
Sophomore Year Spring Semester			
EGGN351 Fluid Mechanics	3		3
MACS315 Differential Equations	3		3
MNGN210 Introductory Mining	3		3
SYGN200 Human Systems	3		3
MNGN317 Dynamics for Mn. Engs.	1		1
EGGN320 Mechanics of Materials	3		3
PAGN202 Physical Education IV		2	0.5
Total			16.5
Summer Field Session			
MNGN300 Summer Field Session			3
Total			3
Junior Year Fall Semester			
EGGN371 Engineering Thermodynamics	3		3
MNGN308 Mine Safety	1		1
MNGN309 Mine Engineering Lab		8	2
MNGN312 Surface Mine Design	2	3	3
MNGN321 Introductory Rock Mechanics	2	3	3
GEOL311 Structural Geology	2		2
Free Elective	3		3
Total			17
Junior Year Spring Semester			
DCGN381 Electrical Circuits, Elec. & Pwr	3		3
LAIS/EBGN H&SS Cluster Elective I	3		3
MNGN314 Underground Mine Design	3		3
MNGN316 Coal Mining Methods and Design	2	3	3
GEOL310 Earth Materials and Resources	4		4
Free Elective	3		3
Total			19
Senior Year Fall Semester			
MNGN408 Underground Design and Const.	2		2
MNGN414 Mine Plant Design	2	3	3
MNGN428 Mining Eng. Design Report I	3		1
MNGN438 Geostatistics	2	3	3
MNGN322/323 Intro. to Mineral Processing	3	2	3
LAIS/EBGN H&SS Cluster Elective II	3		3
Free Elective	3		3
Total			18
Senior Year Spring Semester			
MNGN429 Mining Eng. Design Report II		3	2
MNGN433 Mine Systems Analysis I	3		3
MNGN427 Mine Valuation	2		2
MNGN424 Mine Ventilation	2	3	3
MNGN410 Excavation Project Management	2		2
LAIS/EBGN H&SS Cluster Elective III	3		3
Total			15
Degree Total			139.5

Description of Courses

Freshman Year

MNGN198. SPECIAL TOPICS IN MINING ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

MNGN199. INDEPENDENT STUDY (I, II) (WI) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Sophomore Year

MNGN210. INTRODUCTORY MINING (I, II) Survey of mining and mining economics. Topics include mining law, exploration and sampling, reserve estimation, project evaluation, basic unit operations including drilling, blasting, loading and hauling, support, shaft sinking and an introduction to surface and underground mining methods. Prerequisite: None. 3 hours lecture; 3 semester hours.

MNGN298. SPECIAL TOPICS IN MINING ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

MNGN300. SUMMER FIELD SESSION (S) Classroom and field instructions in the theory and practice of surface and underground mine surveying. Introduction to the application of various computer-aided mine design software packages incorporated in upper division mining courses. Prerequisite: completion of sophomore year; Duration: first three weeks of field term; 3 semester hours.

MNGN317. DYNAMICS FOR MINING ENGINEERS (II) For mining engineering majors only. Absolute and relative motions, kinetics, work-energy, impulse-momentum and angular impulse-momentum. Prerequisite: MACS213/223, DCGN241. 1 hour lecture; 1 semester hour.

Junior Year

MNGN308. MINE SAFETY (I) Causes and prevention of accidents. Mine safety regulations. Mine rescue training. Safety management and organization. Prerequisite: MNGN210. 1 hour lecture; 1 semester hour. Should be taken concurrently with MNGN309.

MNGN309. MINING ENGINEERING LABORATORY (I) Training in practical mine labor functions including: operation of jackleg drills, jumbo drills, muckers, and LHD machines. Training stresses safe operation of equipment and safe handling of explosives. Introduction to front-line management techniques. Prerequisite: MNGN210. 2 semester hours. Should be taken concurrently with MNGN308.

MNGN312. SURFACE MINE DESIGN (I) (WI) 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 and MNGN300. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN316. COAL MINING METHODS (II) (WI) Devoted to surface and underground coal mining methods and design. The surface mining portion emphasizes area-mining methods, including pertinent design-related regulations, and overburden removal systems. Pit layout, sequencing, overburden equipment selection and cost estimation are presented. The underground mining portion emphasizes general mine layout; detailed layout of continuous, conventional, longwall, and shortwall sections. General cost and manning requirements; and production analysis. Federal and state health and safety regulations are included in all aspects of mine layout. Prerequisite: MNGN210. 2 hours lecture, 2 semester hours

MNGN321. INTRODUCTION TO ROCK MECHANICS Physical properties of rock, and fundamentals of rock substance and rock mass response to applied loads. Principles of elastic analysis and stress-strain relationships. Elementary principles of the theoretical and applied design of underground openings and pit slopes. Emphasis on practical applied aspects. Prerequisite: DCGN241 or MNGN317. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN333. EXPLOSIVES ENGINEERING I This course gives students in engineering and applied sciences the opportunity to examine and develop a fundamental knowledge including terminology and understanding of explosives science and engineering concepts. Student learning will be demonstrated by assignments, quizzes, and exams. Learning assistance will come in the form of multidisciplinary lectures complemented by a few experts' lectures from government, industry and the explosives engineering community. 3 semester hours. Pre-requisites: none.

MNGN340. COOPERATIVE EDUCATION (I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

MNGN398. SPECIAL TOPICS IN MINING ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

MNGN399. INDEPENDENT STUDY (I, II) (WI) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Senior Year

MNGN314. UNDERGROUND MINE DESIGN (II) 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 and MNGN300. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN322/323. INTRODUCTION TO MINERAL PROCESSING AND LABORATORY (I) Principles and practice of crushing, grinding, size classification; mineral concentration technologies including magnetic and electrostatic separation, gravity separation, and flotation. Sedimentation, thickening, filtration and product drying as well as tailings disposal technologies are included. The course is open to all CSM students. Prerequisite: PHGN200/210, MACS213/223. 2 hours lecture; 3 hours lab; 3 semester hours.

MNGN404. TUNNELING (I) Modern tunneling techniques. Emphasis on evaluation of ground conditions, estimation of support requirements, methods of tunnel driving and boring, design systems and equipment, and safety. Prerequisite: None. 3 hours lecture; 3 semester hours.

MNGN405. ROCK MECHANICS IN MINING (I) The course deals with the rock mechanics aspect of design of mine layouts developed in both underground and surface. Underground mining sections includes design of coal and hard rock pillars, mine layout design for tabular and massive ore bodies, assessment of caving characteristics of 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: MNGN321 or equivalent. 3 hours lecture; 3 semester hours.

MNGN406. DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS Design of underground excavations and support. Analysis of stress and rock mass deformations around excavations using analytical and numerical methods. Collections, preparation, and evaluation of in situ and laboratory data for excavation design. Use of rock mass rating systems for site characterization and excavation design. Study of support types and selection of support for underground exca-

vations. Use of numerical models for design of shafts, tunnels and large chambers. Prerequisite: Instructor's consent. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN407. ROCK FRAGMENTATION (II) Theory and application of rock drilling, rock boring, explosives, blasting, and mechanical rock breakage. Design of blasting rounds, applications to surface and underground excavation. Prerequisite: DCGN241 concurrent enrollment or instructors consent. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN408 UNDERGROUND DESIGN AND CONSTRUCTION (I) Soil and rock engineering applied to underground civil works. Tunneling and the construction of underground openings for power facilities, water conveyance, transportation, and waste disposal; design, excavation and support of underground openings. Emphasis on consulting practice, case studies, geotechnical design, and construction methods. Prerequisite: EGGN361, MNGN321, or instructor's consent. 2 hours of lecture; 2 semester hours.

MNGN410. EXCAVATION PROJECT MANAGEMENT (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: MNGN 210 or instructors consent, 2-hour lecture, 2 semester hours.

MNGN414. MINE PLANT DESIGN (I) Analysis of mine plant elements with emphasis on design. Materials handling, dewatering, hoisting, belt conveyor and other material handling systems for underground mines. Prerequisite: MNGN312, MNGN314 or consent of lecturer. 0 hours lecture, 3 hours lab; 1 semester hour.

MNGN418. ADVANCED ROCK MECHANICS Analytical and numerical modeling analysis of stresses and displacements induced around engineering excavations in rock. In-situ stress. Rock failure criteria. Complete load deformation behavior of rocks. Measurement and monitoring techniques in rock mechanics. Principles of design of excavation in rocks. Analytical, numerical modeling and empirical design methods. Probabilistic and deterministic approaches to rock engineering designs. Excavation design examples for shafts, tunnels, large chambers and mine pillars. Seismic loading of structures in rock. Phenomenon of rock burst and its alleviation. Prerequisite: MNGN321 or professor's consent. 3 hours lecture; 3 semester hours.

MNGN421. DESIGN OF UNDERGROUND EXCAVATIONS (II) Design of underground openings in competent and broken ground using rock mechanics principles. Rock bolting design and other ground support methods. Coal, evaporite, metallic and nonmetallic deposits included. Prerequisite: MNGN321, concurrent enrollment or instructor's consent. 3 hours lecture; 3 semester hours.

MNGN422/522. FLOTATION Science and engineering governing the practice of mineral concentration by flotation. Interfacial phenomena, flotation reagents, mineral-reagent interactions, and zeta-potential are covered. Flotation circuit design and evaluation as well as tailings handling are also covered. The course also includes laboratory demonstrations of some fundamental concepts. 3 hours lecture; 3 semester hours.

MNGN423. FLOTATION LABORATORY (I) Experiments to accompany the lectures in MNGN422. Corequisite: MNGN421 or consent of instructor. 3 hours lab; 1 semester hour.

MNGN424. MINE VENTILATION (II) Fundamentals of mine ventilation, including control of gas, dust, temperature, and humidity; ventilation network analysis and design of systems. Prerequisite: EGGN351, EGGN371 and MNGN314 or instructors consent. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN427. MINE VALUATION (II) Course emphasis is on the business aspects of mining. Topics include time valuation of money and interest formulas, cash flow, investment criteria, tax considerations, risk and sensitivity analysis, escalation and inflation and cost of capital. Calculation procedures are illustrated by case studies. Computer programs are used. Prerequisite: Senior in Mining, graduate status or consent of instructor. 2 hours lecture; 2 semester hours.

MNGN428. MINING ENGINEERING EVALUATION AND DESIGN REPORT I (I) (WI) Preparation of phase I engineering report based on coordination of all previous work. Includes mineral deposit selection, geologic description, mining method selection, ore reserve determination, and permit process outline. Emphasis is on detailed mine design and cost analysis evaluation in preparation for MNGN429. 3 hours lab; 1 semester hour.

MNGN429. MINING ENGINEERING EVALUATION AND DESIGN REPORT II (II) (WI) Preparation of formal engineering report based on all course work in the mining option. Emphasis is on mine design, equipment selection, production scheduling, evaluation and cost analysis. Prerequisite: MNGN427, 428. 3 hours lab; 2 semester hours.

MNGN431. MINING AND METALLURGICAL ENVIRONMENT This course covers studies of the interface between mining and metallurgical process engineering and environmental engineering areas. Wastes, effluents and their point sources in mining and metallurgical processes such as mineral concentration, value extraction and process metallurgy are studied in context. Fundamentals of unit operations and unit processes with those applicable to waste and effluent control, disposal and materials recycling are covered. Engineering design and engineering cost components are also included for some examples chosen. The ratio of fundamentals applications coverage is about 1:1. Prerequisite: consent of instructor. 3 hours lecture; 3 semester hours.

MNGN433. MINE SYSTEMS ANALYSIS I (II) Application of statistics, systems analysis, and operations research techniques to mineral industry problems. Laboratory work using computer techniques to improve efficiency of mining operations. Prerequisite: Senior or graduate status. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN434. PROCESS ANALYSIS Projects to accompany the lectures in MNGN422. Prerequisite: MNGN422 or consent of instructor. 3 hours lab; 1 semester hour.

MNGN436. UNDERGROUND COAL MINE DESIGN (II) Design of an underground coal mine based on an actual coal reserve. This course shall utilize all previous course material in the actual design of an underground coal mine. Ventilation, materials handling, electrical transmission and distribution, fluid mechanics, equipment selection and application, mine plant design. Information from all basic mining survey courses will be used. Prerequisite: MNGN316, MNGN321, MNGN414, EGGN329 and MNGN381 or MNGN384. Concurrent enrollment with the consent of instructor permitted. 3 hours lecture, 3 hours lab; 3 semester hours.

MNGN438. GEOSTATISTICS (I) Introduction to elementary probability theory and its applications in engineering and sciences; discrete and continuous probability distributions; parameter estimation; hypothesis testing; linear regression; spatial correlations and geostatistics with emphasis on applications in earth sciences and engineering. Prerequisites: MACS112. 2 hours of lecture and 3 hours of lab. 3 semester hours.

MNGN440. EQUIPMENT REPLACEMENT ANALYSIS (I) Introduction to the fundamentals of classical equipment replacement theory. Emphasis on new, practical approaches to equipment replacement decision making. Topics include: operating and maintenance costs, obsolescence factors, technological changes, salvage, capital investments, minimal average annual costs, optimum economic life, infinite and finite planning horizons, replacement cycles, replacement vs. expansion, maximization of returns from equipment replacement expenditures. Prerequisite: MNGN427, senior or graduate status. 2 hours lecture; 2 semester hours.

MNGN444. EXPLOSIVES ENGINEERING II This course gives students in engineering and applied sciences the opportunity to acquire the fundamental concepts of explosives engineering and science applications as they apply to industry and real life examples. Students will expand upon their MNGN333 knowledge and develop a more advanced knowledge base including an understanding of the subject as it applies to their specific project interests. Assignments, quizzes, concept modeling and their project development and presentation will demonstrate student's progress.

MNGN445/545. ROCK SLOPE ENGINEERING 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 determining 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: Instructor's consent. 3 hours lecture. 3 hours semester hours.

MNGN452/552. SOLUTION MINING AND PROCESSING OF ORES (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; instructor's consent. 3 hours lecture, 3 semester hours. Offered in spring.

MNGN460. INDUSTRIAL MINERALS PRODUCTION (II) This course describes the engineering principles and practices associated with quarry mining operations related to the cement and aggregates industries. The course will cover resource definition, quarry planning and design, extraction, and processing of material for cement and aggregate production. Permitting issues and reclamation, particle sizing and environmental practices, will be studied in depth. Prerequisite: MNGN312, MNGN318, MNGN322, MNGN323, or consent of instructor. 3 hours lecture; 3 semester hours. Offered in spring.

MNGN482. MINE MANAGEMENT (II) Basic principles of successful mine management, supervision, administrative policies, industrial and human engineering. Prerequisite: Senior or graduate status or consent of instructor. 2 hours lecture; 2 semester hours. Offered in odd years.

MNGN498. SPECIAL TOPICS IN MINING ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

MNGN499. INDEPENDENT STUDY (I, II) (WI) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Petroleum Engineering

CRAIG W. VAN KIRK, Professor and Department Head
JOHN R. FANCHI, Professor
RAMONA M. GRAVES, Professor
HOSSEIN KAZEMI, Chesebro' Distinguished Professor
ERDAL OZKAN, Professor
RICHARD L. CHRISTIANSEN, Associate Professor
ALFRED W. EUSTES III, Associate Professor
TURHAN YILDIZ, Associate Professor
JENNIFER L. MISKIMINS, Assistant Professor
MARK G. MILLER, Assistant Research Professor
BILLY J. MITCHELL, Professor Emeritus

Program Description

The primary objectives of petroleum engineering are the environmentally sound exploration, development, evaluation, and recovery of oil, gas, and other fluids in the earth. Skills in this branch of engineering are needed to meet the world's ever-increasing demand for hydrocarbon fuel, thermal energy, and waste and pollution management.

Graduates of the program are in high demand in private industry, as evidenced by the strong job market and high salaries. The petroleum industry offers a wide range of employment opportunities for Petroleum Engineering students during summer breaks and after graduation. Exciting experiences range from field work in producing oil and gas fields to office jobs in small towns or large cities. Worldwide travel and overseas assignments are available for interested students. One of our objectives in the Petroleum Engineering Department is to prepare students to succeed in an energy industry that is evolving into an industry working with many energy sources. Besides developing technical competence in petroleum engineering, you will learn how your education can help you contribute to the development of alternative energy sources. In addition to exciting careers in the petroleum industry, many Petroleum Engineering graduates find rewarding careers in the environmental arena, law, medicine, business, and many other walks of life.

The department offers semester-abroad opportunities through formal exchange programs with the Petroleum Engineering Department at the Mining University in Leoben, Austria, Technical University in Delft, Holland, and the University of Adelaide, Adelaide, Australia. Qualified undergraduate and graduate students from each school can attend the other for one semester and receive full transfer credit back at the home university.

Graduate courses emphasize the research aspects of the profession, as well as advanced engineering applications. Qualified graduate students may earn a Professional Masters in Petroleum Reservoir Systems (offered jointly with Geology and Geological Engineering and Geophysics), Master of Science, Master of Engineering, and Doctor of Philosophy degrees.

To facilitate classroom instruction and the learning experience, the petroleum engineering faculty recommend that all petroleum engineering students have laptops for the 2006-07 academic year. Recommended specifications for the laptops can be obtained from the CSM Academic Computing & Networking web site.

A lab wing was completed in 1993 and the existing office and classroom building was renovated in 1994 at a total project cost exceeding \$10 million. New laboratory and computer equipment added during the past few years total more than \$3 million. The department has state-of-the-art laboratories in a wide range of technical areas, including the following under graduate labs:

Computer Laboratory

A state-of-the-art computer laboratory is available for general use and classroom instruction. Software includes more than \$5.0 million in donated industry software used by oil and gas companies and research labs around the world.

Drilling Simulator Laboratory

Rare on university campuses, this lab contains a computer controlled, full-scale, drilling rig simulator. It includes drilling controls that can be used to simulate onshore and offshore drilling operations and well control situations.

Reservoir Characterization Laboratory

Properties of rock are measured that affect economic development of reservoir resources of oil and gas. Measured properties include permeability, porosity, and relative permeability. "Hands on" experiences with simple and sophisticated equipment are provided.

Drilling Fluids Laboratory

Modern equipment enables students to evaluate and design fluid systems required in drilling operations.

Fluids Characterization Laboratory

A variety of properties of fluids from oil and gas reservoirs are measured for realistic conditions of elevated temperature and pressure. This laboratory accentuates principles studied in lectures.

Petroleum Engineering Summer Field Sessions

Two summer sessions, one after the completion of the sophomore year and one after the junior year, are important parts of the educational experience. The first is a two-week session designed to introduce the student to the petroleum industry. Petroleum Engineering, a truly unique and exciting engineering discipline, can be experienced by visiting petroleum operations. Historically, the areas visited have included Europe, Alaska, Canada, the U.S. Gulf Coast, California, and the Rocky Mountain Region.

The second two-week session, after the junior year, is an in-depth study of the Rangely Oil Field and surrounding geology in Western Colorado. The Rangely Oil Field is the largest oil field in the Rocky Mountain region and has undergone primary, secondary, and enhanced recovery processes. Field trips

in the area provide the setting for understanding the complexity of geologic systems and the environmental and safety issues in the context of reservoir development and management.

It is recommended that all students considering majoring or minoring in Petroleum Engineering sign up for the elective course PEGN 102, Introduction to the Petroleum Industry in the spring semester. Seniors may take 500-level graduate courses that include topics such as drilling, reservoir, and production engineering; reservoir simulation and characterization, and economics and risk analysis. See the department for the registration procedure.

The program leading to the degree Bachelor of Science in Petroleum Engineering is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Program Educational Objectives (Bachelor of Science in Petroleum Engineering)

The Mission of the Petroleum Engineering Program has evolved naturally over time in response to the needs of the graduates; in concert with the Colorado School of Mines Institutional Mission Statement and the Profile of the Future Graduate; and in recognition of accreditation requirements specified by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. The Mission of the Petroleum Engineering Program is:

To educate engineers for the worldwide petroleum industry at the undergraduate and graduate levels, perform research that enhances the state-of-the-art in petroleum technology, and to serve the industry and public good through professional societies and public service. This mission is achieved through proactive leadership in providing a solid foundation for both the undergraduate and graduate programs. Students are well prepared for life-long learning, an international and diverse career, further education, and public service. The program emphasizes integrated and multi disciplinary teamwork in classroom instruction and in research, and actively pursues interdisciplinary activities with many other CSM departments, particularly the Earth Science/Engineering programs.

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, individuals interested in the Petroleum Engineering program educational objectives are encouraged to contact faculty, visit the CSM campus, or visit our website: www.mines.edu. The Petroleum Engineering program educational objectives can also be found posted in the hallway outside the department office. The specific educational objectives are outlined below:

1. Broad education

CSM design and system courses

Effective communication

Skills necessary for diverse and international professional career

Recognition of need and ability to engage in lifelong learning

2. Solid foundation in engineering principles and practices

Society of Petroleum Engineers' ABET Program Criteria
 Strong petroleum engineering faculty with diverse backgrounds
 Technical seminars, field trips, and field sessions

3. Applied problem solving skills

Designing and conducting experiments
 Analyzing and interpreting data
 Problem solving skills in engineering practice
 Working real world problems

4. An understanding of ethical, social, environmental, and professional responsibilities

Following established Department and Colorado School of Mines honor codes
 Integrating ethical and environmental issues into real world problems
 Awareness of health and safety issues

5. Multidisciplinary team skills

Integrated information and data from multiple sources
 Critical team skills

Curriculum

All disciplines within petroleum engineering are covered to great depth at the undergraduate and graduate levels, both in the classroom and laboratory instruction, and in research. Specific areas include fundamental fluid and rock behavior, drilling, formation evaluation, well completions and stimulation, well testing, production operations and artificial lift, reservoir engineering, supplemental and enhanced oil recovery, economic evaluation of petroleum projects, environmental and safety issues, and the computer simulation of most of these topics.

The petroleum engineering student studies mathematics, computer science, chemistry, physics, general engineering, the humanities, technical communication (including report writing, oral presentations, and listening skills), and environmental topics. A unique aspect is the breadth and depth of the total program structured in a manner that prepares each graduate for a successful career from the standpoints of technical competence, managerial abilities, and multidisciplinary experiences. The needs for continued learning and professionalism are stressed.

The strength of the program comes from the high quality of students and professors. The faculty has expertise in teaching and research in all the major areas of petroleum engineering listed above. Additionally, the faculty members have significant industrial backgrounds that lead to meaningful design experiences for the students. Engineering design is taught throughout the curriculum including a senior design course on applying the learned skills to real world reservoir development

and management problems. The senior design course is truly multidisciplinary with students and professors from the Petroleum Engineering, Geophysics, and Geology departments.

The program has state-of-the-art facilities and equipment for laboratory instruction and experimental research. To maintain leadership in future petroleum engineering technology, decision making, and management, computers are incorporated into every part of the program, from undergraduate instruction through graduate student and faculty research.

The department is close to oil and gas field operations, oil companies, research laboratories, and geologic outcrops of nearby producing formations. There are many opportunities for short field trips and for summer and part-time employment in the oil and gas industry in the Denver metropolitan region or near campus.

Degree Requirements (Petroleum Engineering)

Sophomore Year Fall Semester	lec.	lab.	sem.hrs.
EBGN201 Principles of Economics	3		3
EPIC251/252 Design II	3		3
DCGN241 Statics	3		3
MACS213 Calculus for Scientists & Engr's III	4		4
PHGN200 Physics II	3.5	3	4.5
PAGN201 Physical Education III		2	0.5
Total			18

Sophomore Year Spring Semester	lec.	lab.	sem.hrs.
DCGN209 Introduction to Thermodynamics	3		3
EGGN320 Mechanics of Materials	3		3
PEGN251 Fluid Mechanics	3		3
PEGN308 Res. Rock Properties	2	3	3
MACS315 Differential Equations	3		3
SYGN200 Human Systems	3		3
Total			18

Summer Field Session	lec.	lab.	sem.hrs.
PEGN315 Summer Field Session I	2		2
Total			2

Junior Year Fall Semester	lec.	lab.	sem.hrs.
GEOL315 Sedimentology & Stratigraphy	2	3	3
PEGN305 Computational Methods	2		2
PEGN310 Reservoir Fluid Properties	2		2
PEGN311 Drilling Engineering	3	3	4
PEGN419 Well Log Anal. & Formation Eval.	2	3	3
LAIS/EBGN H&SS Cluster Elective	1	3	3
PAGN202 Physical Education IV	2	0	.5
Total			17.5

Junior Year Spring Semester	lec.	lab.	sem.hrs.
GEOL308 Intro. Applied Structural Geology	2	3	3
PEGN438 Geostatistics	2	3	3
PEGN361 Well Completions	3		3
PEGN411 Mechanics of Petrol. Production	3		3
LAIS/EBGN H&SS Cluster Elective II	3		3
Free Elective	3		3
Total			18

Summer Field Session	lec.	lab.	sem.hrs.
PEGN316 Summer Field Session II	2		2
Total			2

	lec.	lab.	sem.hrs.
Senior Year Fall Semester			
PEGN481 Petroleum Seminar	2		2
PEGN423 Petroleum Reservoir Eng. I	3		3
PEGN413 Gas Meas. & Formation Evaluation		6	2
PEGN414 Well Test Analysis and Design	3		3
PEGN422 Econ. & Eval. Oil & Gas Projects	3		3
Free Elective	3		3
Total			16
Senior Year Spring Semester			
PEGN424 Petroleum Reservoir Eng. II	3		3
PEGN426 Stimulation	3		3
PEGN439 Multidisciplinary Design	2	3	3
LAI/EBGN H&SS Cluster Elective III	3		3
Free Elective	3		3
Total			15
Degree Total			139.5

Five Year Combined Baccalaureate and Masters Degree.

The Petroleum Engineering Department offers the opportunity to begin work on a Professional Masters in Petroleum Reservoir Systems or Master of Engineering Degree while completing the requirements for the Bachelor's Degree. These degrees are of special interest to those planning on studying abroad or wanting to get a head start on graduate education. These combined programs are individualized and a plan of study should be discussed with the student's academic advisor any time after the Sophomore year.

Description of Courses

Freshman Year

PEGN102. INTRODUCTION TO PETROLEUM INDUSTRY (II) A survey of the elements comprising the petroleum industry-exploration, development, processing, transportation, distribution, engineering ethics and professionalism. This **elective** course is **recommended** for all PE majors, minors, and other interested students. 3 hours lecture; 3 semester hours.

PEGN198. SPECIAL TOPICS IN PETROLEUM ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 semester hours.

PEGN199. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 semester hours.

Sophomore Year

PEGN251. FLUID MECHANICS (II) Fundamental course in engineering fluid flow introducing flow in pipelines, surface facilities and oil and gas wells. Theory and application of incompressible and compressible flow, fluid statics, dimensional analysis, laminar and turbulent flow, Newtonian and non-Newtonian fluids, and two-phase flow. Lecture for-

mat with demonstrations and practical problem solving, coordinated with PEGN 308. Students cannot receive credit for both PEGN 251 Fluid Mechanics and EGGN351 Fluid Mechanics. Prerequisite: MACS213. Co-requisites: PEGN 308, DCGN209, DCGN241. 3 hours lecture; 3 semester hours.

PEGN298. SPECIAL TOPICS IN PETROLEUM ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 semester hours.

PEGN299. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 semester hours.

PEGN308. RESERVOIR ROCK PROPERTIES (II) (WI) Introduction to basic reservoir rock properties and their measurements. Topics covered include: porosity, saturations, volumetric equations, land descriptions, trapping mechanism, pressure and temperature gradients, abnormally pressured reservoirs. Darcy's law for linear horizontal and tilted flow, radial flow for single phase liquids and gases, multiphase flow (relative permeability). Capillary pressure and formation compressibility are also discussed. This course is designated as a writing intensive course (WI). Co-requisites: DCGN241, PEGN251. 2 hours lecture, 3 hours lab; 3 semester hours.

Junior Year

PEGN305 COMPUTATIONAL METHODS IN PETROLEUM ENGINEERING (I) This course is an introduction to computers and computer programming applied to petroleum engineering. Emphasis will be on learning Visual Basic programming techniques to solve engineering problems. A toolbox of fluid property and numerical techniques will be developed. Prerequisite: MACS213. 2 hours lecture; 2 semester hours.

PEGN310. RESERVOIR FLUID PROPERTIES (I) Properties of fluids encountered in petroleum engineering. Phase behavior, density, viscosity, interfacial tension, and composition of oil, gas, and brine systems. Interpreting lab data for engineering applications. Flash calculations with k-values and equation of state. Introduction to reservoir simulation software. Prerequisites: DCGN209, PEGN308. Co-requisite: PEGN305.

PEGN311. DRILLING ENGINEERING (I) Study of drilling operations, fluid design, hydraulics, drilling contracts, rig selection, rotary system, well control, bit selection, drill string design, directional drilling, and casing seat selection. Prerequisites: PEGN251, PEGN315, DCGN241. 3 hours lecture, 3 hours lab; 4 semester hours.

PEGN315. SUMMER FIELD SESSION I (S) This two-week course taken after the completion of the sophomore year is designed to introduce the student to oil and gas field

and other engineering operations. Engineering design problems are integrated throughout the two-week session. On-site visits to various oil field operations in the past included the Rocky Mountain region, the U.S. Gulf Coast, California, Alaska, Canada and Europe. Topics covered include drilling, completions, stimulations, surface facilities, production, artificial lift, reservoir, geology and geophysics. Also included are environmental and safety issues as related to the petroleum industry. Prerequisite: PEGN308. 2 semester hours.

PEGN316. SUMMER FIELD SESSION II (S) This two-week course is taken after the completion of the junior year. Emphasis is placed on the multidisciplinary nature of reservoir management. Field trips in the area provide the opportunity to study eolian, fluvial, lacustrine, near shore, and marine depositional systems. These field trips provide the setting for understanding the complexity of each system in the context of reservoir development and management. Petroleum systems including the source, maturity, and trapping of hydrocarbons are studied in the context of petroleum exploration and development. Geologic methods incorporating both surface and subsurface data are used extensively. Prerequisite: PEGN315, PEGN361, PEGN411, PEGN419 and GEOL308, GEOL315. 2 semester hours.

PEGN340. COOPERATIVE EDUCATION (I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

PEGN350. SUSTAINABLE ENERGY SYSTEMS (I or II) A sustainable energy system is a system that lets us meet present energy needs while preserving the ability of future generations to meet their needs. Sustainable Energy Systems introduces undergraduate students to sustainable energy systems that will be available in the 21st century. The course focuses on sustainable energy sources, especially renewable energy sources and nuclear energy (e.g., fusion). Students are introduced to the existing energy infrastructure, become familiar with finite energy sources, and learn from a study of energy supply and demand that sustainable energy systems are needed. The ability to improve energy use efficiency and the impact of energy sources on the environment are discussed. Examples of sustainable energy systems and their applicability to different energy sectors are presented. The course is recommended for students who plan to enter the energy industry or students who would like an introduction to sustainable energy systems. Prerequisites: EPIC 151 or consent of instructor. 3 hours lecture; 3 semester hours.

PEGN361. COMPLETION ENGINEERING (II) (WI) This class is a continuation from drilling in PEGN311 into completion operations. Topics include casing design, cement

planning, completion techniques and equipment, tubing design, wellhead selection, and sand control, and perforation procedures. This course is designed as a writing intensive course (WI). Prerequisite: PEGN311, EGGN320. 3 hours lecture; 3 semester hours.

PEGN398. SPECIAL TOPICS IN PETROLEUM ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 semester hours.

PEGN399. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 semester hours.

PEGN411. MECHANICS OF PETROLEUM PRODUCTION (II) Nodal analysis for pipe and formation deliverability including single and multiphase flow. Natural flow and design of artificial lift methods including gas lift, sucker rod pumps, electrical submersible pumps, and hydraulic pumps. Prerequisites: PEGN 251, PEGN308, PEGN310, and PEGN311. 3 hours lecture; 3 semester hours.

PEGN419. WELL LOG ANALYSIS AND FORMATION EVALUATION (I) An introduction to well logging methods, including the relationship between measured properties and reservoir properties. Analysis of log suites for reservoir size and content. Graphical and analytical methods will be developed to allow the student to better visualize the reservoir, its contents, and its potential for production. Use of the computer as a tool to handle data, create graphs and log traces, and make computations of reservoir parameters is required. Prerequisite: PEGN308. Co-requisites: PEGN310, GEOL315. 2 hours lecture, 3 hours lab; 3 semester hours.

Senior Year

PEGN413. GAS MEASUREMENT AND FORMATION EVALUATION LAB (I) (WI) This lab investigates the properties of a gas such as vapor pressure, dew point pressure, and field methods of measuring gas volumes. The application of well logging and formation evaluation concepts are also investigated. This course is designated as a writing intensive course (WI). Prerequisites: PEGN308, PEGN310, PEGN419. 6 hours lab; 2 semester hours.

PEGN414. WELL TEST ANALYSIS AND DESIGN (I) Solution to the diffusivity equation. Transient well testing: build-up, drawdown, multi-rate test analysis for oil and gas. Flow tests and well deliverabilities. Type curve analysis. Superposition, active and interference tests. Well test design. Prerequisite: MACS315. 3 hours lecture; 3 semester hours.

PEGN422. ECONOMICS AND EVALUATION OF OIL AND GAS PROJECTS (I) Project economics for oil and gas projects under conditions of certainty and uncertainty. Topics

include time value of money concepts, discount rate assumptions, measures of project profitability, costs, taxes, expected value concept, decision trees, gambler's ruin, and Monte Carlo simulation techniques. Prerequisite: PEGN438/MNGN438. 3 hours lecture; 3 semester hours.

PEGN423. PETROLEUM RESERVOIR ENGINEERING I (I) Data requirements for reservoir engineering studies. Material balance calculations for normal gas, retrograde gas condensate, solution-gas and gas-cap reservoirs with or without water drive. Primary reservoir performance. Forecasting future recoveries by incremental material balance. Prerequisites: PEGN316, PEGN419 and MACS315 (MACS315 only for non PE majors). 3 hours lecture; 3 semester hours.

PEGN424. PETROLEUM RESERVOIR ENGINEERING II (II) Reservoir engineering aspects of supplemental recovery processes. Introduction to liquid-liquid displacement processes, gas-liquid displacement processes, and thermal recovery processes. Introduction to numerical reservoir simulation, history matching and forecasting. Prerequisite: PEGN423. 3 hours lecture; 3 semester hours.

PEGN426. WELL COMPLETIONS AND STIMULATION (II) Completion parameters; design for well conditions. Skin damage associated with completions and well productivity. Fluid types and properties; characterizations of compatibilities. Stimulation techniques; acidizing and fracturing. Selection of proppants and fluids; types, placement and compatibilities. Estimation of rates, volumes and fracture dimensions. Reservoir considerations in fracture propagation and design. Prerequisite: PEGN311, PEGN361, PEGN411 and MACS315. 3 hours lecture; 3 semester hours.

PEGN428. ADVANCED DRILLING ENGINEERING (II) Rotary drilling systems with emphasis on design of drilling programs, directional and horizontal well planning. This **elective** course is **recommended** for petroleum engineering majors interested in drilling. Prerequisite: PEGN311, PEGN361. 3 hours lecture; 3 semester hours.

PEGN438/MNGN438. GEOSTATISTICS (I & II) Introduction to elementary probability theory and its applications in engineering and sciences; discrete and continuous probability distributions; parameter estimation; hypothesis testing; linear regression; spatial correlations and geostatistics with emphasis on applications in earth sciences and engineering. Prerequisites: MACS115. 2 hours lecture; 3 hours lab; 3 semester hours.

PEGN439/GEGN439/GPGN439. MULTIDISCIPLINARY PETROLEUM DESIGN (II) This is a multidisciplinary design course that integrates fundamentals and design concepts in geology, geophysics, and petroleum engineering. Students work in integrated teams consisting of students from each of the disciplines. Multiple open-ended design problems in oil and gas exploration and field development are assigned. Several written and oral presentations are made throughout the semester. Project economics including risk analysis are an integral part of the course. Prerequisite: PE Majors: GEOL308, PEGN316, PEGN422, PEGN423, PEGN414. Concurrent enrollment in PEGN424; GE Majors: GEOL308 or GEOL309, GEGN438, GEGN316; GP Majors: GPGN302 and GPGN303. 2 hours lecture, 3 hours lab; 3 semester hours.

PEGN450. ENERGY ENGINEERING (I or II) Energy Engineering is an overview of energy sources that will be available for use in the 21st century. After discussing the history of energy and its contribution to society, we survey the science and technology of energy, including geothermal energy, fossil energy, solar energy, nuclear energy, wind energy, hydro energy, bio energy, energy and the environment, energy and economics, the hydrogen economy, and energy forecasts. This broad background will give you additional flexibility during your career and help you thrive in an energy industry that is evolving from an industry dominated by fossil fuels to an industry working with many energy sources. Prerequisite: MACS213, PHGN200. 3 hours lecture; 3 semester hours.

PEGN481. PETROLEUM SEMINAR (I) (WI) Written and oral presentations by each student on current energy topics. This course is designated as a writing intensive course (WI). Prerequisite: Consent of instructor. 2 hours lecture; 2 semester hours.

PEGN498. SPECIAL TOPICS IN PETROLEUM ENGINEERING (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 semester hours.

PEGN499. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 semester hours.

Physics

JAMES A. McNEIL, Professor and Department Head
REUBEN T. COLLINS, Professor
JOHN A. DESANTO, Professor
THOMAS E. FURTAK, Professor
FRANK V. KOWALSKI, Professor
MARK T. LUSK, Professor (and Engineering)
JOHN A. SCALES, Professor
JEFF A. SQUIER, Professor
P. CRAIG TAYLOR, Professor
CHARLES G. DURFEE, III, Associate Professor
UWE GREIFE, Associate Professor
TIMOTHY R. OHNO, Associate Professor
DAVID M. WOOD, Associate Professor
LINCOLN D. CARR, Assistant Professor
FREDERIC SARAZIN, Assistant Professor
TODD G. RUSKELL, Senior Lecturer
MATTHEW M. YOUNG, Senior Lecturer
ANITA B. CORN, Lecturer
ALEX T. FLOURNOY, Lecturer
H. VINCENT KUO, Lecturer
SUE ANNE BERGER, Instructor
P. DAVID FLAMMER, Instructor
CHRISTOPHER M. KELSO, Instructor
JAMES T. BROWN, Professor Emeritus
F. EDWARD CECIL, Professor Emeritus
FRANKLIN D. SCHOWENGERDT, Professor Emeritus
JOHN U. TREFNY, Professor Emeritus and President Emeritus
DON L. WILLIAMSON, Professor Emeritus
F. RICHARD YEATTS, Professor Emeritus
WILLIAM B. LAW, Associate Professor Emeritus
ARTHUR Y. SAKAKURA, Associate Professor Emeritus
MARK W. COFFEY, Research Professor
ROBERT F. HOLUB, Research Professor
VICTOR KAYDANOV, Research Professor
JAMES E. BERNARD, Research Associate Professor
JOSEPH D. BEACH, Research Assistant Professor

Program Description

Engineering Physics

Physics is the most basic of all sciences and the foundation of most of the science and engineering disciplines. As such, it has always attracted those who want to understand nature at its most fundamental level. Engineering Physics is not a specialized branch of physics, but an interdisciplinary area wherein the basic physics subject matter, which forms the backbone of any undergraduate physics degree, is taken further toward application to engineering. The degree is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700. At CSM, the required engineering physics curriculum includes all of the undergraduate physics courses that would form the physics curriculum at any good university, but in addition to these basic courses, the CSM requirements include pre-engineering and engineering courses, which physics majors at other universities would not

ordinarily take. These courses include engineering science, design, systems, summer field session, and a capstone senior design sequence culminating in a senior thesis.

This unique blend of physics and engineering makes it possible for the engineering physics graduate to work at the interface between science and technology, where new discoveries are continually being put to practice. While the engineering physicist is at home applying existing technologies, he or she is also capable of striking out in different directions to develop new technologies. It is the excitement of being able to work at this cutting edge that makes the engineering physics degree attractive to many students.

Career paths of CSM engineering physics graduates vary widely, illustrating the flexibility inherent in the program. Approximately half of the graduating seniors go on to graduate school in physics or a closely related field of engineering. Some go to medical, law, or other professional post-graduate schools. Others find employment in fields as diverse as electronics, semiconductor processing, aerospace, materials development, nuclear energy, solar energy, and geophysical exploration.

The physics department maintains modern well-equipped laboratories for general physics, modern physics, electronics, and advanced experimentation. There are research laboratories for the study of solid-state physics, surface physics, materials science, optics, and nuclear physics, including an NSF-funded laboratory for solar and electronic materials processing. The department also maintains electronic and machine shops.

Program Educational Objectives (Bachelor of Science in Engineering Physics)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the physics department embraces the broad institutional educational objectives as summarized in the Graduate Profile. The additional engineering physics program-specific educational objectives are listed below.

All engineering physics graduates must have the factual knowledge and other thinking skills necessary to construct an appropriate understanding of physical phenomena in an applied context.

All engineering physics graduates must have the ability to communicate effectively.

Throughout their careers engineering physics graduates should be able to function effectively and responsibly in society.

Five-year Combined Baccalaureate / Masters Degree Programs

The Physics Department, independently, and in collaboration with the Department of Metallurgical and Materials Engineering and with the Engineering Division offers five-year

programs in which students obtain an undergraduate degree in Engineering Physics as well as a Masters Degree in Applied Physics or an Engineering discipline. There are three engineering tracks and three physics tracks. The first two lead to a Masters degree in Engineering with a mechanical or electrical specialty. Students in the third track receive a Masters of Metallurgical and Materials Engineering with an electronic materials emphasis. The Applied Physics tracks are in the areas of condensed matter, applied optics, and applied nuclear physics. The programs emphasize a strong background in fundamentals of science, in addition to practical experience within an applied physics or engineering discipline. Many of the undergraduate electives of students involved in each track are specified. For this reason, students are expected to apply to the program during the first semester of their sophomore year (in special cases late entry can be approved by the program mentors). A 3.0 grade point average must be maintained to guarantee admission into the appropriate engineering or applied physics graduate program.

Students in the engineering tracks must complete a report or case study during the fifth year. Students in the physics tracks must complete a master's thesis. The case study or thesis should begin during the senior year as part of the Senior Design experience. Participants must identify an engineering or physics advisor as appropriate prior to their senior year who will assist in choosing an appropriate project and help coordinate the senior design project with the case study or thesis completed in the fifth year.

Interested students can obtain additional information and detailed curricula from the Physics Department or from the participating Engineering Departments.

Minor and Areas of Special Interest

The department offers a Minor and Areas of Special Interest for students not majoring in physics. The requirements are as follows:

Area of Specialization: 12 sem. hrs. minimum (includes 3 semester hours of PHGN100 or 200)

Minor: 18 sem. hrs. minimum (includes 3 semester hours of PHGN100 or 200)

Two courses (one year) of modern physics:

PHGN300 Modern Physics I 3 sem. hrs. and

PHGN320 Modern Physics II 4 sem. hrs.

One course:

PHGN341 Thermal Physics 3 sem. hrs. or

PHGN350 Mechanics 4 sem. hrs. or

PHGN361 Electromagnetism 3 sem. hrs.

Selected courses to complete the Minor: Upper division and/or graduate (500-level) courses which form a logical sequence in a specific field of study as determined in consultation with the Physics Department and the student's option department.

Degree Requirements (Engineering Physics)

Sophomore Year Fall Semester	lec.	lab.	sem.hrs.
MACS213 Calculus for Scientists & Eng'n's III	4		4
PHGN200 Physics II	3.5	3	4.5
EPIC251 Design II	3		3
SYGN200 Human Systems	3		3
PAGN201 Physical Education III	2		0.5
Total			15

Sophomore Year Spring Semester	lec.	lab.	sem.hrs.
MACS315 Differential Equations	3		3
DCGN210 Introduction to Thermodynamics	3		3
PHGN300/310 Physics III-Modern Physics I	3		3
PHGN215 Analog Electronics	3	3	4
EBGN201 Principles of Economics	3		3
PAGN202 Physical Education IV	2		0.5
Total			16.5

Summer Field Session	lec.	lab.	sem.hrs.
PHGN384 Summer Field Session (6 weeks)			6
Total			6

Junior Year Fall Semester	lec.	lab.	sem.hrs.
PHGN315 Advanced Physics Lab I (WI)	1	3	2
PGHN311 Introduction to Math. Physics	3		3
LAIS/EBGN H&SS Cluster Elective I	3		3
PHGN317 Digital Circuits	2	3	3
PHGN350 Intermediate Mechanics	4		4
Total			15

Year Spring Semester	lec.	lab.	sem.hrs.
PHGN361 Intermediate Electromagnetism	3		3
PHGN320 Modern Physics II	4		4
PHGN326 Advanced Physics Lab II (WI)	1	3	2
PHGN341 Thermal Physics	3		3
Free Elective I	3		3
Total			15

Senior Year Fall Semester	lec.	lab.	sem.hrs.
PHGN471 Senior Design I (WI)	1	6	3
PHGN462 Electromag. Waves & Opt. Physics	3		3
LAIS/EBGN H&SS Cluster Elective II	3		3
Free Elective II	3		3
Free Elective III	3		3
Total			15

Senior Year Spring Semester	lec.	lab.	sem.hrs.
PHGN472 Senior Design II (WI)	1	6	3
LAIS/EBGN H&SS Cluster Elective III	3		3
Engineering Science Elective	3		3
Free Elective IV	3		3
Free Elective V	3		3
Total			15

Degree Total 130.5

Description of Courses

PHGN100. PHYSICS I - MECHANICS (I, II, S) A first course in physics covering the basic principles of mechanics using vectors and calculus. The course consists of a fundamental treatment of the concepts and applications of kinematics and dynamics of particles and systems of particles, including Newton's laws, energy and momentum, rotation,

oscillations, and waves. Prerequisite: MACS111 and concurrent enrollment in MACS112/122 or consent of instructor. 2 hours lecture; 4 hours studio; 4.5 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1.

PHGN110. HONORS PHYSICS I - MECHANICS A course parallel to PHGN100 but in which the subject matter is treated in greater depth. Registration is restricted to students who are particularly interested in physics and can be expected to show above-average ability. Usually an A or B grade in MACS111/121 is expected. Prerequisite: MACS111 and concurrent enrollment in MACS112/122 or consent of instructor. 2 hours lecture; 4 hours studio; 4.5 semester hours.

PHGN198. SPECIAL TOPICS (I, II) Pilot course or special topics course. Prerequisite: Consent of Department. Credit to be determined by instructor, maximum of 6 credit hours.

PHGN199. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Sophomore Year

PHGN200. PHYSICS II-ELECTROMAGNETISM AND OPTICS (I, II, S) Continuation of PHGN100. Introduction to the fundamental laws and concepts of electricity and magnetism, electromagnetic devices, electromagnetic behavior of materials, applications to simple circuits, electromagnetic radiation, and an introduction to optical phenomena. Prerequisite: PHGN100/110, concurrent enrollment in MACS213/223. 3 hours lecture; 1 hour recitation; 1.5 hours lab; 4.5 semester hours.

PHGN210. HONORS PHYSICS II-ELECTROMAGNETISM AND OPTICS A course parallel to PHGN200 but in which the subject matter is treated in greater depth. Registration is restricted to students who show particular interest and ability in the subject of physics. Usually an A or B grade in PHGN110 or an A grade in PHGN100 is expected. Prerequisite: PHGN100/110, concurrent enrollment in MACS213/223. 3 hours lecture; 1 hour recitation; 1.5 hours lab; 4.5 semester hours.

PHGN215 ANALOG ELECTRONICS (II) Introduction to analog devices used in modern electronics and basic topics in electrical engineering. Introduction to methods of electronics measurements, particularly the application of oscilloscopes and computer based data acquisition. Topics covered include circuit analysis, electrical power, diodes, transistors (FET and BJT), operational amplifiers, filters, transducers, and integrated circuits. Laboratory experiments in the use of basic electronics for physical measurements. Emphasis is on practical knowledge gained in the laboratory, including

prototyping, troubleshooting, and laboratory notebook style. Prerequisite: PHGN200. 3 hours lecture, 3 hours lab; 4 semester hours.

PHGN298. SPECIAL TOPICS (I, II) Pilot course or special topics course. Prerequisite: Consent of Department. Credit to be determined by instructor, maximum of 6 credit hours.

Junior Year

PHGN300. PHYSICS III-MODERN PHYSICS I (I, II, S) The third course in introductory physics for scientists and engineers including an introduction to the special theory of relativity, wave-particle duality, the Schroedinger equation, electrons in solids, nuclear structure and transmutations. Prerequisite: PHGN200/210; Concurrent enrollment in MACS315. 3 hours lecture; 3 semester hours.

PHGN310. HONORS PHYSICS III-MODERN PHYSICS (II) A course parallel to PHGN300 but in which the subject matter is treated in greater depth. Registration is strongly recommended for physics majors or those considering the physics option, but is not required. Prerequisite: PHGN200/210 and concurrent enrollment in MACS315 or consent of instructor. 3 hours lecture; 3 semester hours.

PHGN311. INTRODUCTION TO MATHEMATICAL PHYSICS Demonstration of the unity of diverse topics such as mechanics, quantum mechanics, optics, and electricity and magnetism via the techniques of linear algebra, complex variables, Fourier transforms, and vector calculus. Prerequisite: PHGN300, MACS315, and PHGN384 or consent of instructor. 3 hours lecture; 3 semester hours.

PHGN315. ADVANCED PHYSICS LAB I (I) (WI) Introduction to laboratory measurement techniques as applied to modern physics experiments. Experiments from optics and atomic physics. A writing-intensive course with laboratory and computer design projects based on applications of modern physics. Prerequisite: PHGN300/310 or consent of instructor. 1 hour lecture, 3 hours lab; 2 semester hours.

PHGN317. SEMICONDUCTOR CIRCUITS- DIGITAL (I) Introduction to digital devices used in modern electronics. Topics covered include logic gates, flip-flops, timers, counters, multiplexing, analog-to-digital and digital-to-analog devices. Emphasis is on practical circuit design and assembly. Prerequisite: PHGN215. 2 hours lecture, 3 hours lab; 3 semester hours.

PHGN320 MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS (II) Introduction to the Schroedinger theory of quantum mechanics. Topics include Schroedinger's equation, quantum theory of measurement, the uncertainty principle, eigenfunctions and energy spectra, angular momentum, perturbation theory, and the treatment of identical particles. Example applications taken from atomic, molecular, solid state or nuclear systems. Prerequisites: PHGN300 and PHGN311. 4 hours lecture; 4 semester hours.

PHGN324. INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS (II) Celestial mechanics; Kepler's laws and gravitation; solar system and its contents; electromagnetic radiation and matter; stars: distances, magnitudes, spectral classification, structure, and evolution. Variable and unusual stars, pulsars and neutron stars, supernovae, black holes, and models of the origin and evolution of the universe. Prerequisite: PHGN200/210. 3 hours lecture; 3 semester hours.

PHGN326. ADVANCED PHYSICS LAB II (II) (WI) Continuation of PHGN315. A writing-intensive course which expands laboratory experiments to include nuclear and solid state physics. Prerequisite: PHGN315. 1 hour lecture, 3 hours lab; 2 semester hours.

PHGN333/BELS333. INTRODUCTION TO BIOPHYSICS This course is designed to show the application of physics to biology. It will assess the relationships between sequence structure and function in complex biological networks and the interfaces between physics, chemistry, biology and medicine. Topics include: biological membranes, biological mechanics and movement, neural networks, medical imaging basics including optical methods, MRI, isotopic tracers and CT, biomagnetism and pharmacokinetics. Prerequisites: PHGN 200 and BELS301/ESGN301, or permission of the instructor, 3 hours lecture, 3 semester hours

PHGN340. COOPERATIVE EDUCATION (I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours.

PHGN341. THERMAL PHYSICS (II) An introduction to statistical physics from the quantum mechanical point of view. The microcanonical and canonical ensembles. Heat, work and the laws of thermodynamics. Thermodynamic potentials; Maxwell relations; phase transformations. Elementary kinetic theory. An introduction to quantum statistics. Prerequisite: DCGN210 and PHGN311. 3 hours lecture; 3 semester hours.

PHGN350. INTERMEDIATE MECHANICS (I) Begins with an intermediate treatment of Newtonian mechanics and continues through an introduction to Hamilton's principle and Hamiltonian and Lagrangian dynamics. Includes systems of particles, linear and driven oscillators, motion under a central force, two-particle collisions and scattering, motion in non-inertial reference frames and dynamics of rigid bodies. Prerequisite: PHGN200/210. Co-requisite: PHGN311. 4 hours lecture; 4 semester hours.

PHGN361. INTERMEDIATE ELECTROMAGNETISM (II) Theory and application of the following: static electric and magnetic fields in free space, dielectric materials, and magnetic materials; steady currents; scalar and vector potentials; Gauss' law and Laplace's equation applied to boundary

value problems; Ampere's and Faraday's laws. Prerequisite: PHGN200/210 and PHGN311. 3 hours lecture; 3 semester hours.

PHGN384. APPARATUS DESIGN (S) Introduction to the design of engineering physics apparatus. Concentrated individual participation in the design of machined and fabricated system components, vacuum systems, electronics and computer interfacing systems. Supplementary lectures on safety and laboratory techniques. Visits to regional research facilities and industrial plants. Prerequisite: PHGN300/310, PHGN215. Available in 4 or 6 credit hour blocks in the summer field session usually following the sophomore year. The machine shop component also may be available in a 2-hour block during the academic year. Total of 6 credit hours required for the Engineering Physics option.

PHGN398. SPECIAL TOPICS (I, II) Pilot course or special topics course. Prerequisites: Consent of department. Credit to be determined by instructor, maximum of 6 credit hours.

PHGN399. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Senior Year

PHGN402. GREAT PHYSICISTS The lives, times, and scientific contributions of key historical physicists are explored in an informal seminar format. Each week a member of the faculty will lead discussions about one or more different scientists who have figured significantly in the development of the discipline. Prerequisite: None. 1 hour lecture; 1 semester hour.

PHGN404. PHYSICS OF THE ENVIRONMENT An examination of several environmental issues in terms of the fundamental underlying principles of physics including energy conservation, conversion and generation; solar energy; nuclear power and weapons, radioactivity and radiation effects; aspects of air, noise and thermal pollution. Prerequisite: PHGN200/210 or consent of instructor. 3 hours lecture; 3 semester hours.

PHGN412. MATHEMATICAL PHYSICS Mathematical techniques applied to the equations of physics; complex variables, partial differential equations, special functions, finite and infinite-dimensional vector spaces. Green's functions. Transforms; computer algebra. Prerequisite: PHGN311. 3 hours lecture; 3 semester hours.

PHGN419. PRINCIPLES OF SOLAR ENERGY SYSTEMS Theory and techniques of insolation measurement. Absorptive and radiative properties of surfaces. Optical properties of materials and surfaces. Principles of photovoltaic devices. Optics of collector systems. Solar energy conversion techniques: heating and cooling of buildings, solar thermal (power and process heat), wind energy, ocean thermal, and photovoltaic. Prerequisite: PHGN300/310 and MACS315.

PHGN420. QUANTUM MECHANICS Schroedinger equation, uncertainty, change of representation, one-dimensional problems, axioms for state vectors and operators, matrix mechanics, uncertainty relations, time-independent perturbation theory, time-dependent perturbations, harmonic oscillator, angular momentum. Prerequisite: PHGN320 and PHGN350. 3 hours lecture; 3 semester hours.

PHGN421. ATOMIC PHYSICS Introduction to the fundamental properties and structure of atoms. Applications to hydrogen-like atoms, fine-structure multielectron atoms, and atomic spectra. Prerequisite: PHGN320. 3 hours lecture; 3 semester hours.

PHGN422. NUCLEAR PHYSICS Introduction to subatomic (particle and nuclear) phenomena. Characterization and systematics of particle and nuclear states; symmetries; introduction and systematics of the electromagnetic, weak, and strong interactions; systematics of radioactivity; liquid drop and shell models; nuclear technology. Prerequisite: PHGN320. 3 hours lecture; 3 semester hours.

PHGN423. DIRECT ENERGY CONVERSION Review of basic physical principles; types of power generation treated include fission, fusion, magnetohydrodynamic, thermoelectric, thermionic, fuel cells, photovoltaic, electrohydrodynamic piezoelectrics. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN424. ASTROPHYSICS A survey of fundamental aspects of astrophysical phenomena, concentrating on measurements of basic stellar properties such as distance, luminosity, spectral classification, mass, and radii. Simple models of stellar structure evolution and the associated nuclear processes as sources of energy and nucleosynthesis. Introduction to cosmology and physics of standard big-bang models. Prerequisite: PHGN320. 3 hours lecture; 3 semester hours.

PHGN435/ChEN435. INTERDISCIPLINARY MICRO-ELECTRONICS PROCESSING LABORATORY Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisites: Senior standing in PHGN, CRGN, MTGN, or EGGN. Consent of instructor. 1.5 hours lecture, 4 hours lab; 3 semester hours.

PHGN440/MLGN502. SOLID STATE PHYSICS An elementary study of the properties of solids including crystalline structure and its determination, lattice vibrations, electrons in metals, and semiconductors. (Graduate students in physics may register only for PHGN440.) Prerequisite: PH320. 3 hours lecture; 3 semester hours.

PHGN441/MLGN522. SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA Continuation of PHGN440/MLGN502 with an emphasis on applications of the principles of solid state physics to practical properties of materials including: optical properties, superconductivity, dielectric

properties, magnetism, noncrystalline structure, and interfaces. (Graduate students in physics may register only for PHGN441.) Prerequisite: PHGN440/MLGN502, or equivalent by instructor's permission. 3 hours lecture; 3 semester hours.

PHGN450. COMPUTATIONAL PHYSICS Introduction to numerical methods for analyzing advanced physics problems. Topics covered include finite element methods, analysis of scaling, efficiency, errors, and stability, as well as a survey of numerical algorithms and packages for analyzing algebraic, differential, and matrix systems. The numerical methods are introduced and developed in the analysis of advanced physics problems taken from classical physics, astrophysics, electromagnetism, solid state, and nuclear physics. Prerequisites: Introductory-level knowledge of C, Fortran, or Basic; PHGN311. 3 hours lecture; 3 semester hours.

PHGN460. PLASMA PHYSICS Review of Maxwell's equations; charged-particle orbit in given electromagnetic fields; macroscopic behavior of plasma, distribution functions; diffusion theory; kinetic equations of plasma; plasma oscillations and waves, conductivity, magnetohydrodynamics, stability theory; Alven waves, plasma confinement. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN462. ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS (I) Solutions to the electromagnetic wave equation are studied, including plane waves, guided waves, refraction, interference, diffraction and polarization; applications in optics; imaging, lasers, resonators and wave guides. Prerequisite: PHGN361. 3 hours lecture; 3 semester hours.

PHGN466. MODERN OPTICAL ENGINEERING Provides students with a comprehensive working knowledge of optical system design that is sufficient to address optical problems found in their respective disciplines. Topics include paraxial optics, imaging, aberration analysis, use of commercial ray tracing and optimization, diffraction, linear systems and optical transfer functions, detectors and optical system examples. Prerequisite: PHGN462 or consent of instructor. 3 hours lecture; 3 semester hours.

PHGN471. SENIOR DESIGN (I) (WI) The first of a two-semester program covering the full spectrum of experimental design, drawing on all of the student's previous course work. At the beginning of the first semester, the student selects a research project in consultation with the course coordinator and the faculty supervisor. The objectives of the project are given to the student in broad outline form. The student then designs the entire project, including any or all of the following elements as appropriate: literature search, specialized apparatus, block-diagram electronics, computer data acquisition and/or analysis, sample materials, and measurement and/or analysis sequences. The course culminates in a senior thesis. Supplementary lectures are given on techniques of physics research and experimental design. Prerequisite: PHGN384 and PHGN326. 1 hour lecture, 6 hours lab; 3 semester hours.

PHGN472. SENIOR DESIGN (II) (WI) Continuation of PHGN471. Prerequisite: PHGN384 and PHGN326. 1 hour lecture, 6 hours lab; 3 semester hours.

PHGN498. SPECIAL TOPICS (I, II) Pilot course or special topics course. Prerequisites: Consent of instructor. Credit to be determined by instructor, maximum of 6 credit hours.

PHGN499. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, student and instructor agree on a subject matter, content, deliverables, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Bioengineering and Life Sciences (BELS)

Minors and Areas of Special Interest Only

PHILIPPE E. ROSS, Professor and BELS Director

JOEL M. BACH, Associate Professor and BELS Associate Director

Department of Chemistry and Geochemistry

PAUL W. JAGODZINSKI, Professor

KENT J. VOORHEES, Professor

KEVIN W. MANDERNACK, Associate Professor

JAMES F. RANVILLE, Associate Professor

KIM R. WILLIAMS, Associate Professor

DAVID T. WU, Associate Professor

Department of Chemical Engineering

JAMES F. ELY, Professor and Head

ANNETTE L. BUNGE, Professor

JOHN R. DORGAN, Professor

DAVID T. WU, Associate Professor

Division of Engineering

JOEL M. BACH, Associate Professor

WILLIAM A. HOFF, Associate Professor

JAMES CAROLLO, Assistant Research Professor

Division of Environmental Science and Engineering

ROBERT L. SIEGRIST, Professor and Director

PHILIPPE E. ROSS, Professor

RONALD R. H. COHEN, Associate Professor

LINDA A. FIGUEROA, Associate Professor

JUNKO MUNAKATA MARR, Associate Professor

JOHN R. SPEAR, Assistant Professor

MICHAEL SEIBERT, Research Professor

MARIA L. GHIRARDI, Research Associate Professor

MATTHEW C. POSEWITZ, Research Assistant Professor

Department of Geology and Geological Engineering

MURRAY W. HITZMAN, Professor and Head: Charles Franklin

Fogarty Distinguished Chair in Economic Geology

MICHAEL GOOSEFF, Assistant Professor

Division of Liberal Arts and International Studies

ARTHUR B. SACKS, Professor and Associate Vice President for

Academic and Faculty Affairs

LAURA PANG, Associate Professor and Division Director

TINA L. GIANQUITTO, Assistant Professor

Department of Mathematical and Computer Sciences

GRAEME FAIRWEATHER, Professor and Head

DINESH MEHTA, Professor

WILLIAM C. NAVIDI, Professor

HUGH KING, Senior Lecturer

Department of Metallurgical and Materials Engineering

JOHN J. MOORE, Trustees Professor and Head

GERALD P. MARTINS, Professor

PATRICK R. TAYLOR, Professor

HANS-JOACHIM KLEEBE, Associate Professor

IVAR E. REIMANIS, Professor

REED AYERS, Research Assistant Professor (Center for Commercial

Applications of Combustion in Space)

Department of Physics

JAMES A. McNEIL, Professor and Head

THOMAS E. FURTAK, Professor

JEFF SQUIER, Professor

Programs Offered:

Minor in Bioengineering and Life Sciences

Area of Special Interest in Bioengineering and Life Sciences

Program Description

The program in Bioengineering and Life Sciences (BELS) is administered jointly by the Divisions of Engineering, Environmental Science and Engineering, and Liberal Arts and International Studies, and by the Departments of Chemical Engineering, Chemistry and Geochemistry, Geology and Geological Engineering, Mathematical and Computer Sciences, Metallurgical and Materials Engineering, and Physics. Each division or department is represented on both the Board of Directors and the Curriculum and Research Committee, which are responsible for the operation of the program.

The mission of the BELS program is to offer Minors and Areas of Special Interest (ASI) at the undergraduate level, and support areas of specialization at the graduate level, as well as to enable research opportunities for CSM students in bioengineering and the life sciences.

Bioengineering and the Life Sciences (BELS) are becoming increasingly significant in fulfilling the role and mission of the Colorado School of Mines. Many intellectual frontiers within the fields of environment, energy, materials, and their associated fields of science and engineering, are being driven by advances in the biosciences and the application of engineering to living processes.

Program Requirements:

Minor in Bioengineering and Life Sciences:

The Minor in BELS requires a minimum of 18 semester hours of acceptable coursework, as outlined under the Required Curriculum section which follows.

The Area of Special Interest (ASI) in BELS requires a minimum of 12 semester hours of acceptable coursework, as outlined under the Required Curriculum section which follows.

Enrollments in the BELS Minor and ASI are approved by the Associate Director, who monitors progress and completion.

Required Curriculum:

Both the Minor and the ASI require one core course (three semester hours). The minor requires at least six additional credit hours from the Basic Life Science course list, and additional BELS-approved courses to make up a total of at least 18 credit hours. The ASI requires at least three additional credit hours from the Life Science course list, and additional BELS-approved courses to make up a total of at least 12 credit hours.

Core Course:

BELS301/ESGN301 General Biology I

Basic Life Science courses:

BELS303/ESGN303 General Biology II

BELS311/ESGN311 General Biology I Laboratory

BELS313/ESGN313 General Biology II Laboratory

BELS321/ESGN321 Introduction to Genetics

BELS402/ESGN402 Cell Biology and Physiology

BELS404 Anatomy and Physiology

CHGN428 Biochemistry I

CHGN462/CHGC562/ESGN580 Microbiology & the Environment

CHGN563/CHGC563/ESGN582 Environmental Microbiology Lab

BELS-approved Elective courses (including, but not limited to):

BELS325/LAIS320 Introduction to Ethics

BELS333/PHGN333 Introduction to Biophysics

BELS398 Special Topics in Bioengineering and Life Sciences

BELS415/ChEN415 Polymer Science and Technology

BELS420/EGGN420 Intro to Biomedical Engineering

BELS425/EGGN425 Musculoskeletal Biomechanics

BELS430/EGGN430 Biomedical Instrumentation

BELS433/MACS433 Mathematical Biology

BELS453/EGGN453/ESGN453 Wastewater Engineering

BELS498 Special Topics in Bioengineering and Life Sciences

BELS525/EGES525 Musculoskeletal Biomechanics

BELS530/EGES530 Biomedical Instrumentation

BELS541/ESGN541 Biochemical Treatment Processes

CHGN422 Polymer Chemistry Laboratory

CHGN508 Analytical Spectroscopy

MLGN523 Applied Surface & Solution Chem.

ESGN401 Fundamentals of Ecology

ESGN544 Aquatic Toxicology

ESGN596 Molecular Environmental Biotechnology

ESGN545 Environmental Toxicology

ESGN586 Microbiology of Engineered Environmental Systems

*CHGN221 Organic Chemistry I

(for students whose major program does not require it)

*CHGN222 Organic Chemistry II

(for students whose major program does not require it)

BELS570/MTGN570/MLGN570 Intro to Biocompatibility

Premedical Students

While medical college admissions requirements vary, most require a minimum of:

two semesters of General Chemistry with lab

two semesters of Organic Chemistry with lab

two semesters of Calculus

two semesters of Calculus-based Physics

two semesters of English Literature and Composition

two semesters of General Biology with lab.

CSM currently offers all of these requirements *except* the two General Biology labs. These courses can be taken through a collaborative agreement at Red Rocks Community college or at other local universities and colleges.

*Note: Only three hours of Organic Chemistry course credit may be applied toward the BELS minor or ASI. General rules for Minor Programs and Areas of Special Interest (page 36 of this Bulletin) indicate that for a minor no more than three credit hours may be taken in the student's degree-granting department, and that for the ASI no more than three credit hours may be specifically required by the degree program in which the student is graduating.

Description of Courses

BELS301/ESGN301. GENERAL BIOLOGY I (I and II)

This is the first semester of an introductory course in Biology. Emphasis is placed on the methods of science; structural, molecular, and energetic basis of cellular activities; genetic variability and evolution; diversity and life processes in plants and animals; and, principles of ecology. Prerequisite: None. 3 hours lecture; 3 hours semester hours.

BELS311/ESGN311. GENERAL BIOLOGY I LABORATORY(I) This Course provides students with laboratory exercises that complement lectures given in ESGN301/BELS301, the first semester introductory course in Biology. Emphasis is placed on the methods of science; structural, molecular, and energetic basis of cellular activities; genetic variability and evolution; diversity and life processes in plants and animals; and, principles of ecology. Offered with the collaboration of Red Rocks Community College Co-requisite or Prerequisite: EGGS/BELS301 or equivalent. 3 hours laboratory; 1 semester hour.

BELS303/ESGN303 GENERAL BIOLOGY II (II) This is the continuation of General Biology I. Emphasis is placed on an examination of organisms as the products of evolution. The diversity of life forms will be explored. Special attention will be given to the vertebrate body (organs, tissues, and systems) and how it functions. Prerequisite: General Biology I, or equivalent. 3 hours lecture; 3 semester hours.

BELS313/ESGN313. GENERAL BIOLOGY II LABORATORY (II) This Course provides students with laboratory exercises that complement lectures given in ESGN303/BELS303, the second semester introductory course in Biology. Emphasis is placed on an examination of organisms as the products of evolution. The diversity of life forms will be explored. Special attention will be given to the vertebrate body (organs, tissues and systems) and how it functions. Offered with the collaboration of Red Rocks Community College. Co-requisite or Prerequisite: ESGN/BELS303 or equivalent. 3 hours laboratory; 1 semester hour.

BELS321/ESGN321. INTRO TO GENETICS (II) A study of the mechanisms by which biological information is encoded, stored, and transmitted, including Mendelian genetics, molecular genetics, chromosome structure and rearrangement, cytogenetics, and population genetics. Prerequisite: General biology I or equivalent. 3 hours lecture + 3 hours laboratory; 4 semester hours.

BELS325/LAIS320 INTRODUCTION TO ETHICS

A general introduction to ethics that explores its analytic and historical traditions. Reference will commonly be made to one or more significant texts by such moral philosophers as Plato, Aristotle, Augustine, Thomas Aquinas, Kant, John Stuart Mill, and others.

BELS333/PHGN333 INTRODUCTION TO BIOPHYSICS

This course is designed to show the application of physics to

biology. It will assess the relationships between sequence structure and function in complex biological networks and the interfaces between physics, chemistry, biology and medicine. Topics include: biological membranes, biological mechanics and movement, neural networks, medical imaging basics including optical methods, MRI, isotopic tracers and CT, biomagnetism and pharmacokinetics. Prerequisites: PHGN 200 and BELS301/ESGN301, or permission of the instructor. 3 hours lecture, 3 semester hours

BELS398 SPECIAL TOPICS IN BIOENGINEERING AND LIFE SCIENCES Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit: 1 to 6 credit hours.

BELS402/ESGN402. CELL BIOLOGY AND PHYSIOLOGY (II) An introduction to the morphological, biochemical, and biophysical properties of cells and their significance in the life processes. Prerequisite: General Biology I, or equivalent. 3 hours lecture; 3 semester hours.

BELS404. ANATOMY AND PHYSIOLOGY (II) This course will cover the basics of human anatomy and physiology. We will discuss the gross and microscopic anatomy and the physiology of the major organ systems. Where possible we will integrate discussions of disease processes and introduce reliant biomedical engineering concepts. Prerequisite: None. 3 hours lecture; 3 semester hours.

BELS420/EGGN420. INTRO TO BIOMEDICAL ENGINEERING (I) The application of engineering principles and techniques to the human body presents many unique challenges. Biomedical Engineering is a diverse, seemingly all-encompassing field that includes such areas as biomechanics, bioinstrumentation, medical imaging, and rehabilitation. This course is intended to provide an introduction to, and overview of, Biomedical Engineering. Prerequisites: DCGN241, DCGN381, EGGN320, EGGN351 (co-requisite or instructor permission). 3 hours lecture; 3 semester hours.

BELS425/EGGN425 MUSCULOSKELETAL BIOMECHANICS This course is intended to provide engineering students with an introduction to musculoskeletal biomechanics. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply engineering principles to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. Prerequisites: DCGN421 Statics, EGGN320 Mechanics of Materials, EGGN420/BELS420 Introduction to Biomedical Engineering (or instructor permission). 3 hours lecture; 3 semester hours.

BELS430/EGGN430 BIOMEDICAL INSTRUMENTATION The acquisition, processing, and interpretation of biological signals presents many unique challenges to the Biomedical Engineer. This course is intended to provide students with an introduction to, and appreciation for, many of 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, DCGN381 Introduction to Electrical Circuits, Electronics, and Power, EGGN420/BELS420 Introduction to Biomedical Engineering (or permission of instructor). 3 hours lecture; 3 semester hours.

BELS498 SPECIAL TOPICS IN BIOENGINEERING AND LIFE SCIENCES Pilot course or special topics course.

Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit: 1 to 6 credit hours.

BELS525/EGGN525. MUSCULOSKELETAL BIOMECHANICS (II) This course is intended to provide engineering students with an introduction to musculoskeletal biomechanics. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply engineering principles to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. Prerequisites: DCGN241, EGGN320, EGGN420 (or instructor permission). 3 hours lecture; 3 semester hours.

BELS530/EGGN530. BIOMEDICAL INSTRUMENTATION (II) The acquisition, processing, and interpretation of biological signals present many unique challenges to the Biomedical Engineer. This course is intended to provide students with an introduction to, and appreciation for, many of 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, DCGN381, BELS420/EGGN420 (or permission of instructor). 3 hours lecture; 3 semester hours.

BELS415/ChEN415. POLYMER SCIENCE AND TECHNOLOGY Chemistry and thermodynamics of polymers and polymer solutions. Reaction engineering of polymerization. Characterization techniques based on solution properties. Materials science of polymers in varying physical states. Processing operations for polymeric materials and use in separations. Prerequisite: CHGN211, MACS315, ChEN357, or consent of instructor. 3 hours lecture; 3 semester hours.

BELS433/MACS433. MATHEMATICAL BIOLOGY (I) This course will discuss methods for building and solving both continuous and discrete mathematical models. These methods will be applied to population dynamics, epidemic spread, pharmacokinetics and modeling of physiologic systems. Modern Control Theory will be introduced and used to model living systems. Some concepts related to self-organizing systems will be introduced. Prerequisite: MACS315. 3 hours lecture, 3 semester hours.

BELS525/EGES525 MUSCULOSKELETAL BIOMECHANICS This course is intended to provide graduate engineering students with an introduction to musculoskeletal

biomechanics. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply engineering principles to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. Prerequisites: DCGN421 Statics, EGGN320 Mechanics of Materials, EGGN420/BELS420 Introduction to Biomedical Engineering (or instructor permission). 3 hours lecture; 3 semester hours.

BELS530/EGES530 BIOMEDICAL INSTRUMENTATION 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, DCGN381 Introduction to Electrical Circuits, Electronics, and Power, EGGN420/BELS420 Introduction to Biomedical Engineering (or permission of instructor). 3 hours lecture; 3 semester hours.

BELS541/ESGN541. BIOCHEMICAL TREATMENT PROCESSES The analysis and design of biochemical processes used to transform pollutants are investigated in this course. Suspended growth, attached growth, and porous media systems will be analyzed. Common biochemical operations used for water, wastewater, and sludge treatment will be discussed. Biochemical systems for organic oxidation and fermentation and inorganic oxidation and reduction will be presented. Prerequisites: ESGN504 or consent of the instructor. 3 hours lecture; 3 semester hours.

BELS453/EGGN453/ESGN453. WASTEWATER ENGINEERING (I) The goal of this course is to familiarize students with the fundamental phenomena involved in wastewater treatment processes (theory) and the engineering approaches used in designing such processes (design). This course will focus on the physical, chemical and biological processes applied to liquid wastes of municipal origin. Treatment objectives will be discussed as the driving force for wastewater treatment. Prerequisite: ESGN353 or consent of instructor. 3 hours lecture; 3 semester hours.

CHGN422. INTRO TO POLYMER CHEMISTRY LABORATORY (I) Prerequisites: CHGN221. 3 hours lab; 1 semester hour.

CHGN428. BIOCHEMISTRY I (I) Introductory study of the major molecules of biochemistry: amino acids, proteins, enzymes, nucleic acids, lipids, and saccharides- their structure, chemistry, biological function, and biosynthesis. Stresses bioenergetics and the cell as a biological unit of organization. Discussion of classical genetics, molecular genetics, and protein synthesis. Prerequisite: CHGN221 or permission of instructor. 3 hours lecture; 3 semester hours.

CHGN462/CHGC562/ESGN580. MICROBIOLOGY & THE ENVIRONMENT This course will cover the basic fundamentals of microbiology, such as structure and function of prokaryotic versus eukaryotic cells; viruses; classification of microorganisms; microbial metabolism, energetics, genetics, growth and diversity, microbial interactions with plants, animals, and other microbes. Additional topics covered will include various aspects of environmental microbiology such as global biogeochemical cycles, bioleaching, bioremediation, and wastewater treatment. Prerequisite: Consent of instructor 3 hours lecture, 3 semester hours. Offered in alternate years.

CHGN508. ANALYTICAL SPECTROSCOPY (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: Consent of instructor. 3 hours lecture; 3 semester hours. Offered alternate years.

MLGN532. APPLIED SURFACE & SOLUTION CHEMISTRY. (I) Solution and surface chemistry of importance in mineral and metallurgical operations. Prerequisite: Consent of department. 3 semester hours. (Fall of even years only.)

BELS544/ESGN544. AQUATIC TOXICOLOGY (II) An introduction to assessing the effects of toxic substances on aquatic organisms, communities, and ecosystems. Topics include general toxicological principles, water quality standards, 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 lab; 3 semester hours.

BELS596/ESGN596. MOLECULAR ENVIRONMENTAL BIOTECHNOLOGY (I) Applications of recombinant DNA technology to the development of enzymes and organisms used for environmentally friendly industrial purposes. Topics include genetic engineering technology, biocatalysis of industrial processes by extremozymes, dye synthesis, biodegradation of aromatic compounds and chlorinated solvents, biosynthesis of polymers and fuels, and agricultural biotechnology. Prerequisite: introductory microbiology and organic chemistry or consent of the instructor. 3 hours lecture; 3 semester hours.

BELS545/ESGN545. ENVIRONMENTAL TOXICOLOGY (II) 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.

CHGN563/ESGN582. MICROBIOLOGY AND THE ENVIRONMENT LAB. (I) 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: Consent of instructor. 1 hour lecture, 3 hours lab; 2 semester hours. Offered alternate years.

ESGN 401 – FUNDAMENTALS OF ECOLOGY (II). Biological and ecological principles discussed and industrial examples of their use given. Analysis of ecosystem processes, such as erosion, succession, and how these processes relate to engineering activities, including engineering design and plant operation. Criteria and performance standards analyzed for facility siting, pollution control, and mitigation of impacts. North American ecosystems analyzed. Concepts of forestry, range, and wildlife management integrated as they apply to all of the above. Three to four weekend trips will be arranged during the semester. 3 lecture hours, 3 semester hours.

ESGN586. MICROBIOLOGY OF ENGINEERED ENVIRONMENTAL SYSTEMS (I) Applications of microbial physiological processes to engineered and human-impacted systems for the purpose of achieving environmentally desirable results. Topics include microbial identification and enumeration, biofilms in engineered systems, industrial fermentations and respirations, biodegradation and bioremediation of organic and inorganic contaminants, wastewater microbiology, renewable energy generation, and agricultural biotechnology. Prerequisite: CHGC562 or equivalent, or enrollment in an ESE program. 3 hours lecture, 3 semester hours.

CHGN221. ORGANIC CHEMISTRY I (I) Structure, properties, and reactions of the important classes of organic compounds, introduction to reaction mechanisms. Laboratory exercises including synthesis, product purification and characterization. Prerequisite: CHGN124, CHGN126. 3 hours lecture; 3 hours lab; 4 semester hours.

CHGN222. ORGANIC CHEMISTRY II (II) Continuation of CHGN221. Prerequisite: CHGN221. 3 hours lecture; 3 hours lab; 4 semester hours.

BELS570/MTGN570/MLGN570. INTRO TO BIOCOMPATIBILITY Material biocompatibility is a function of tissue/implant mechanics, implant morphology and surface chemistry. The interaction of the physiologic environment with a material is present at each of these levels, with subjects including material mechanical/structural matching to surrounding tissues, tissue responses to materials (inflammation, immune response), anabolic cellular responses and tissue engineering of new tissues on scaffold materials. This course is intended for senior level undergraduates and first year graduate students.

Energy Minor

John R. Fanchi, Professor and Energy Minor Director
Marcelo Simoes, Associate Professor and Energy Minor
Co-Director

Division of Economics and Business

CAROL DAHL, Professor

Division of Engineering

P.K. SEN, Professor
MARCELO SIMOES, Associate Professor

Department of Geology and Geological Engineering

JOHN CURTIS, Professor

Department of Petroleum Engineering

JOHN R. FANCHI, Professor

Department of Physics

P. CRAIG TAYLOR, Professor

Division of Liberal Arts and International Studies

LAURA PANG, Associate Professor and Division Director
CARL MITCHAM, Professor
JOHN HEILBRUNN, Assistant Professor

Programs Offered:

Minor in Energy

Program Educational Objectives

Six CSM departments and divisions have combined resources to offer a Minor Program in Energy. The Energy Minor provides a formal structure for recognizing student participation in a set of multidisciplinary courses that are linked by their importance to global energy. Courses for the minor can be chosen in consultation with an Energy program advisor from a list of approved courses.

The mission of the Energy Minor at the Colorado School of Mines is to offer opportunities for undergraduate students to explore the technical and societal dimensions of energy production and use as these have been manifested in the past and are likely to exist in the future. The Energy Minor provides a formal structure for recognizing student participation in a set of multidisciplinary courses that are linked by their importance to global energy. Students are expected to take an energy survey course to become familiar with a range of energy alternatives and issues, and to take courses that examine the relationship between energy and society. In addition, students will take a set of technical courses for a more in-depth study of specific energy options of their choice. Courses for the minor can be chosen in consultation with an Energy program advisor from the list of courses presented below.

Program Requirements:

Minor in Energy:

The minor requires a minimum of 18 credit hours of acceptable coursework in courses listed below. Up to 3 hours of coursework may be taken in the student's degree-granting department. The following list presents the courses that have been approved for the Energy Minor.

Energy Survey Course (select one):

PEGN 350: Sustainable Energy Systems

PEGN 450: Energy Engineering

Energy and Society Courses (select two):

EBGN 330: Energy Economics

LAIS 442: Natural Resources and War in Africa

LAIS 452: Corruption and Development

LAIS 486: Science and Technology Policy

Technical Energy Courses (select three):

ChEN 408: Natural Gas Processing

ChEN 409: Petroleum Processes

ChEN 498 / EGGN 498: Fuel Cell Science & Technology

EGGN 389: Fundamentals of Electric Machinery I

EGGN 403: Thermodynamics II

EGGN 486: Practical Design of Small Renewable Energy Systems

GEGN 438: Petroleum Geology I

PHGN 423: Direct Energy Conversion

Materials Science

(Interdisciplinary Program)

The interdisciplinary Materials Science Program is administered jointly by the Departments of Chemical Engineering and Petroleum Refining, Chemistry and Geochemistry, Metallurgical and Materials Engineering, Physics and the Division of Engineering. Each department is represented on both the Governing Board and the Graduate Affairs Committee which are responsible for the operation of the program.

Listed below are 400-level undergraduate courses which are cross-listed with 500-level Materials Science courses. Additional courses offered by the Program Departments, not listed here, may also satisfy the course-requirements towards a graduate degree in this Program. Consult the Materials Science Program Guidelines for Graduate Students and the Program Departments course-listings. It should be noted that the course requirement for graduate-level registration for a MLGN "500"-level course which is cross-listed with a 400-level course-number, will include an additional course-component above that required for 400-level credit.

MLGN502/PHGN440. SOLID STATE PHYSICS (II)

An elementary study of the properties of solids including crystalline structure and its determination, lattice vibrations, electrons in metals, and semiconductors. Prerequisite: PHGN300 or PHGN325 and MACS315. 3 hours lecture; 3 semester hours.

MLGN505*/MTGN445. MECHANICAL PROPERTIES OF MATERIALS (I)

Mechanical properties and relationships. Plastic deformation of crystalline materials. Relationships of microstructures to mechanical strength. Fracture, creep, and fatigue. Prerequisite: MTGN348. 3 hours lecture; 3 hours lab; 3*³/₄ semester hours. * This is a 3 hour-credit graduate-course in the Materials Science Program and a 4 hour-credit undergraduate-course in the MTGN program.

MLGN510/CHGN410 SURFACE CHEMISTRY (I) Introduction to colloid systems, capillarity, surface tension and contact angle, adsorption from solution, micelles and micro-emulsions, the solid/gas interface, surface analytical techniques, van der Waal forces, electrical properties and colloid stability, some specific colloid systems (clays, foams and emulsions). Students enrolled for graduate credit in MLGN510 must complete a special project. Prerequisite: DCGN209 or consent of instructor. 3 hours lecture; 3 semester hours.

MLGN512/MTGN412. CERAMIC ENGINEERING (II)

Application of engineering principles to nonmetallic and ceramic materials. Processing of raw materials and production of ceramic bodies, glazes, glasses, enamels, and cements. Firing processes and reactions in glass bonded as well as mechanically bonded systems. Prerequisite: MTGN348. 3 hours lecture; 3 semester hours.

MLGN515/MTGN415. ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS (II) Survey of the electrical properties of materials, and the applications of materi-

als as electrical circuit components. The effects of chemistry, processing, and microstructure on the electrical properties will be discussed, along with functions, performance requirements, and testing methods of materials for each type of circuit component. The general topics covered are conductors, resistors, insulators, capacitors, energy converters, magnetic materials, and integrated circuits. Prerequisites: PHGN200/210, MTGN311 or MLGN501, MTGN412/MLGN512, or consent of instructor. 3 hours lecture; 3 semester hours.

MLGN516/MTGN416 PROPERTIES OF CERAMICS (II)

A survey of the properties of ceramic materials and how these properties are determined by the chemical structure (composition), crystal structure, and the microstructure of crystalline ceramics and glasses. Thermal, optical, and mechanical properties of single-phase and multi-phase ceramics, including composites, are covered. Prerequisites: PHGN200/210, MTGN311 or MLGN501, MTGN412/MLGN512 or consent of instructor. 3 hours lecture; 3 semester hours

MLGN517/EGGN422 SOLID MECHANICS OF MATERIALS (I)

Review mechanics of materials. Introduction to elastic and non-linear continua. Cartesian tensors and stresses and strains. Analytical solution of elasticity problems. Develop basic concepts of fracture mechanics. Prerequisite: EGGN320 or equivalent, MACS315 or equivalent. 3 hours lecture; 3 semester hours. Semester to be offered: Spring

MLGN519/MTGN419. NON-CRYSTALLINE MATERIALS (II)

An introduction to the principles of glass science-and-engineering and non-crystalline materials in general. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisites: MTGN311 or MLGN501, MLGN512/MTGN412, or consent of instructor. 3 hours lecture; 3 semester hours.

MLGN522/PHGN441. SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA

Continuation of MLGN502/PHGN440 with an emphasis on applications of the principles of solid state physics to practical properties of materials including optical properties, superconductivity, dielectric properties, magnetism, noncrystalline structure, and interfaces. Graduate students in physics cannot receive credit for MLGN522, only PHGN441. Prerequisite: MLGN502/PHGN440. 3 hours lecture; 3 semester hours. Those receiving graduate credit will be required to submit a term paper, in addition to satisfying all of the other requirements of the course.

MLGN530/CHGN430/CRGN415. INTRODUCTION TO POLYMER SCIENCE (I)

An introduction to the chemistry and physics of macromolecules. Topics include the properties and statistics of polymer solutions, measurements of molecular weights, molecular weight distributions, properties of bulk polymers, mechanisms of polymer formation, and properties of thermosets and thermoplasts including elastomers. Prerequisite: CHGN327 or consent of instructor. 3 hours lecture; 3 semester hours.

MLGN531/CRGN416. INTRODUCTION TO POLYMER ENGINEERING (II) This class provides a background in polymer fluid mechanics, polymer rheological response and polymer shape forming. The class begins with a discussion of the definition and measurement of material properties. Interrelationships among the material response functions are elucidated and relevant correlations between experimental data and material response in real flow situations are given. Processing operations for polymeric materials will then be addressed. These include the flow of polymers through circular, slit, and complex dies. Fiber spinning, film blowing, extrusion and coextrusion will be covered as will injection molding. Graduate students are required to write a term paper and take separate examinations which are at a more advanced level. Prerequisite: CHEN307, EGGN351 or equivalent. 3 hours lecture; 3 semester hours.

MLGN544/MTGN414 PROCESSING OF CERAMICS (II) A description of the principles of ceramic processing and the relationship between processing and microstructure. Raw materials and raw material preparation, forming and fabrication, thermal processing, and finishing of ceramic materials will be covered. Principles will be illustrated by case studies on specific ceramic materials. A project to design a ceramic fabrication process is required. Field trips to local ceramic manufacturing operations are included. Prerequisites: MTGN311, MTGN331, and MTGN412/MLGN512 or consent of instructor. 3 hours lecture; 3 semester hours.

MLGN550/MLGN450. STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS (II) An introduction to statistical process control, process capability analysis and experimental design techniques. Statistical process control theory and techniques will be developed and applied to control charts for variables and attributes involved in process control and evaluation. Process capability concepts will be developed and applied for the evaluation of manufacturing processes. The theory and application of designed experiments will be developed and applied for full factorial experiments, fractional factorial experiments, screening experiments, multilevel experiments and mixture experiments. Analysis of designed experiments will be carried out by graphical and statistical techniques. Computer software will be utilized for statistical process control and for the design and analysis of experiments. Prerequisite: Consent of Instructor. 3 hours lecture, 3 semester hours.

Guy T. McBride, Jr. Honors Program in Public Affairs for Engineers

DR. LORING ABEYTA, Interim Principal Tutor and Program Director

Program Educational Objectives

The McBride Honors Program in Public Affairs for Engineers offers 24 semester hours of seminars and off-campus activities that have the primary educational objective of providing a select number of CSM students the opportunity to cross the boundaries of their technical expertise into the ethical, cultural, and socio-political dimensions of science and technology. Students will gain the values, knowledge, and skills to prove, project, and test the moral and social implications of their future professional judgments and activities, not only for the particular organizations with which they will be involved, but also for the nation and the world. To achieve this educational objective, the program seeks to bring themes from the humanities and the social sciences into the CSM curriculum to develop in students the habits of thought necessary for effective management, social and environmental responsibility, and enlightened leadership.

Program Description

Designed and taught by teams of faculty members from the humanities, social sciences, life and physical sciences, and engineering, the curriculum of the McBride Honors Program in Public Affairs for Engineers features the following educational experiences:

- ◆ Student-centered seminars guided by faculty moderators from various disciplines.
- ◆ An interdisciplinary approach that integrates domestic and global perspectives into the curriculum.
- ◆ One-to-one long-lasting relationships between faculty and students.
- ◆ Development and practice of oral/written communication and listening skills.
- ◆ Opportunity to travel to Washington, DC and abroad as part of the McBride curriculum.
- ◆ Intellectual relationships and camaraderie.
- ◆ Public affairs or policy related internship.

A central experience in the program is the Practicum (an internship, overseas study, public service, or thesis), which usually comes during the summer following the junior year. Because engineers and scientists will continue to assume significant responsibilities as leaders in public and private sectors, it is essential that CSM students be prepared for more than the traditional first jobs in industry. Leadership and management demand an understanding of the accelerating pace of change that marks the social, political, and eco-

conomic currents of society and a commitment to social and environmental responsibility. While the seminars in the program are designed to nourish such an understanding, the goal of the internship is to put students into situations where they may see firsthand the kinds of challenges that they will face in their professional lives.

Foreign study is also possible either through CSM-sponsored trips or through individual plans arranged in consultation with the Principal Tutor and CSM's Office of International Programs. The cost for any foreign study is the responsibility of the student.

Student Profile

The McBride Honors Program in Public Affairs for Engineers seeks to enroll students who can profit most from the learning experiences upon which the program is based while significantly contributing to faculty and peer learning. Whereas most conventional honors programs admit students almost exclusively on the basis of academic record, in the McBride Honors Program test scores, grade point, and class rank form only part of the criteria used in the admission process. Applicants must demonstrate their leadership potential, commitment to public service, willingness to understand and respect perspectives other than their own, and writing, listening, and speaking abilities through an essay and an interview with faculty members.

Once admitted into the program, a McBride student commits to

- ◆ completing the 24-credit-hour McBride curriculum as stated in the catalog, deviating from this program of studies only with permission from the program administration;
- ◆ participating in the McBride seminars as an active and responsible learner, always completing reading and writing assignments in order to be ready to teach and learn from peers and instructors;
- ◆ engaging in the highest level of intellectual discourse in a civil and respectful manner with all members of the CSM community, even with those who hold different beliefs, values, and views of the world;
- ◆ accepting and behaving according to the rules established for the Washington Policy and Foreign Area Study trips to ensure the safety of peers, maximize the educational experience of the group, and maintain CSM's high reputation;
- ◆ accepting responsibility for grades, which means that s/he will earn the grade that s/he deserves given his/her level of commitment and respect to the learning process;
- ◆ understanding that McBride's academic standards require students to maintain a minimum GPA of 2.9 at all times, otherwise the student will be placed on academic probation in the Program;

- ◆ understanding that the McBride faculty is committed to provide the best education to help students become thoughtful and responsible persons and professionals;
- ◆ upholding the highest standards of ethical conduct, particularly those related to academic honesty and respect for peers;
- ◆ accepting CSM educational goals, particularly those related to meeting the *Profile of the Colorado School of Mines*.

Although the educational experiences in the McBride Honors Program are rigorous and demand a high degree of persistence from the students, McBride graduates have gained positions of their choice in industry and government more easily than others and have been successful in winning admission to high-quality graduate and professional schools.

Admission

Interested students should apply to the McBride program during the summer prior to their first semester of freshman year by filling out an application, writing an essay, and securing letters of recommendation (see website for details). Applicants will be interviewed in September by a team of faculty and Honor students. Finalists will be announced in October. Once a finalist accepts the responsibilities and honors of being a member of the Program (see above), s/he begins taking Honors seminars in the Spring semester of freshmen year.

Transfer and Graduation Policies

The McBride Program accepts applications from transfer students as follows:

- ◆ Transfer students who enter CSM in the Fall semester must fill out an application and go through the application and interview process with all freshmen applicants (see above).
- ◆ Transfer students who enter CSM in the Spring semester must submit a full application, including the essay, and arrange an interview with the Principal Moderator and the Chair of McBride's Executive Committee before the first day of Spring semester classes.

All transfer students should expect to take the entire McBride curriculum (24 credit hours) in residence. Only under very *special circumstances*, the Principal Tutor will assess a petition by a transfer student for course substitutions.

Academic Standards

Because of the nature of the program, students are expected to commit to the highest levels of writing, reading, and discussion before and during McBride seminars. Participation in class projects and discussions is essential. Students who do not maintain an appropriate level of such participation may be asked to leave the program.

Academic integrity and honesty are expected of the students in the program. Any infractions in these areas will be handled under the rules of CSM and may result in dismissal from the program.

The program demands a high level of achievement not only in honors courses, but in all academic work attempted. To that end, a student must meet the following requirements:

- ◆ A minimum cumulative GPA of 2.9 (based on the average undergraduate GPA on campus) in all course work at CSM at any given time.
- ◆ A minimum GPA of 3.0 in Honors coursework to remain in good academic standing.
- ◆ A minimum cumulative GPA of 2.9 and an Honors GPA of 3.0 at the time of graduation in order to receive the “Minor in the McBride Honors Program in Public Affairs”. Graduating seniors who fall below these minimums will receive a “Minor in Public Affairs.”

A student who falls below any of these minimums will be placed on probation for one semester. If the required minimum GPA has not been met at the end of that semester, the student will be dropped from the program.

Description of Courses

HNRS101. PARADOXES OF THE HUMAN CONDITION Study of the paradoxes in the human condition as expressed in significant texts in classics, literature, moral philosophy, and history; drama and music, both classical and contemporary, history, biography, and fiction. Prerequisite: Freshman status in the McBride Honors Program. 3 hours seminar; 3 semester hours.

HNRS201. CULTURAL ANTHROPOLOGY: A STUDY OF DIVERSE CULTURES A study of cultures within the United States and abroad and the behavior of people. The seminar will emphasize the roles of languages, religions, moral values, and legal and economic systems in the cultures selected for inquiry. Prerequisite: HNRS101 or consent of the Principal Tutor. 3 hours seminar; 3 semester hours.

HNRS202. COMPARATIVE POLITICAL AND ECONOMIC SYSTEMS This course constitutes a comparative study of the interrelationships between political and economic systems in theory and practice. Totalitarianism, authoritarianism, democracy, anarchy, socialism, and communism will be examined in their historical and theoretical contexts and compared with baseline concepts of what constitutes a political system. Economics will be studied from a historical/developmental approach, examining classical and neo-classical economics and theories of major western economists, including Smith, Marx, and Keynes. Specific nation or area case studies will be used to integrate concepts and to explore possible new global conditions which define the roles of governments and other institutions in the development, planning, and control of economic activities and social pol-

icy. Prerequisite: HNRS201 or permission of the Principal Tutor. 3 hours seminar; 3 semester hours.

HNRS301. INTERNATIONAL POLITICAL ECONOMY International political economy is the study of the dynamic relationships between nation-states and the global marketplace. Topics include: international and world politics, money and international finance, international trade, multinational and global corporations, global development, transition economies and societies, and developing economies and societies. Prerequisite: HNRS202 or permission of Principal Tutor. 3 hours seminar; 3 semester hours.

HNRS302. TECHNOLOGY AND SOCIO-ECONOMIC CHANGE A critical analysis of the interactions among science, technology, and American values and institutions. The seminar will study the role of technology in American society and will debate the implications of technology transfer from developed to developing nations. Students will learn to relate technological issues to socio-economic and religious aspects of society and explore the moral and social consequences of technological innovations. Prerequisite: HNRS202 or permission of Principal Tutor. 3 hours seminar; 3 semester hours.

HNRS311. U.S. PUBLIC POLICY: DOMESTIC AND FOREIGN Detailed examination of United States public policy, using a case study approach to guide students to understand the various aspects of policy making and the participants in the process. As an outcome of this seminar, students will have the ability to engage in informed, critical analysis of public policy, and will understand the process and how they may become involved in it. Students should expect to spend spring break in Washington, D.C., as part of this seminar. Prerequisite: HNRS301 or HNRS302 or permission of Principal Tutor. 3 hours seminar; 3 semester hours.

HNRS312 FOREIGN AREA STUDY A survey of current public policy issues of a selected country or region, based on a broad survey of history and culture as well as contemporary social, technological, economic and political trends. The areas that might be studied in a three year rotation; Far East (China and Taiwan or Hong Kong, Indonesia and/or Malaysia), Latin America (Brazil or Chile), Middle East/Africa (Turkey or South Africa). Students taking this seminar in preparation for a McBride sponsored trip abroad might be able to take a brief intensive language course before departure. Prerequisite: HNRS301 or HNRS302 or permission of Principal Tutor. 3 hours seminar; 3 semester hours.

HNRS401. MCBRIDE PRACTICUM: INTERNSHIP An off-campus practicum which may include an internship in a company, government agency, or public service organization (domestic or foreign), or foreign study as a part of a McBride group or individually. The practicum must have prior approval of the Principal Tutor. All students completing a practicum are expected to keep an extensive journal and write a professional report detailing, analyzing, and evaluating their

experiences. Prerequisite: HNRS311. 3 hours seminar; 3 semester hours.

HNRS402. MCBRIDE PRACTICUM: FOREIGN AREA STUDY FIELD TRIP After completing the HNRS312 Foreign Area Study seminar, students travel to the selected country or region. Students will gain first hand experience interacting and communicating with people from another culture. Students will complete a written research and analysis report using historic cultural, technological, political, or an economic theme. Prerequisite: HNRS312 or permission of Principal Tutor. 3 hours seminar, 3 semester hours.

HNRS411. STUDY OF LEADERSHIP AND POWER An intellectual examination into the nature of leadership and power. Focuses on understanding and interpreting the leadership role, both its potential and its limitations, in various historical, literary, political, socio-economic, and cultural contexts. Exemplary leaders and their antitypes are analyzed. Characteristics of leaders are related to their cultural and temporal context. This course will ask questions regarding the morality of power and its uses. Leadership in technical and non-technical environments will be compared and contrasted. Additionally, power and empowerment, and the complications of becoming or of confronting a leader are scrutinized. Prerequisite: HNRS311 or HNRS312 or permission of Principal Tutor. 3 hours seminar; 3 semester hours.

HNRS412. CONFLICT RESOLUTION An in-depth look at creative, non-violent, non-litigious, win-win ways to handle conflicts in personal, business, environmental and governmental settings. The class will learn concepts, theories and methods of conflict resolution, study past and present cases, and observe on-going conflict resolution efforts in the Denver area. Prerequisite: HNRS311 or HNRS312 or permission of Principal Tutor. 3 hour seminar. 3 semester hours.

HNRS420. SCIENCE, TECHNOLOGY, AND ETHICS A comprehensive inquiry into ethical and moral issues raised by modern science and technology. Issues covered include: the contention that science is value neutral; the particular sorts of ethical problems faced by engineers in their public and political roles in deciding uses of materials and energy; the personal problems faced in the development of a career in science and technology; the moral dilemmas inherent in using natural forms and energies for human purposes; and the technologically dominated modern civilization. The seminar will consist of readings and discussion of ethical issues in plays, works of fiction, and films. Prerequisite: HNRS411 or HNRS412 or permission of the Principal Tutor. 3 hours seminar; 3 semester hours.

Military Science (Army ROTC-AROTC)

The Military Science Program at the Colorado School of Mines develops the qualities of citizenship and leadership in the individual which are desirable in both military and civilian enterprises. Successful completion of the four-year program qualifies the student for a commission as a Second Lieutenant in the United States Army, Army Reserve or Army National Guard. Full benefit of the program is achieved by participating in the four-year program; however, late entry may be possible by attendance at the summer Basic Camp.

Basic Course. (Freshman and Sophomore-level Military Science): No obligation is incurred by enrolling in any Freshman or Sophomore-level Military Science course (except by Military Science Scholarship winners). Students receive training in military skills such as drill and ceremonies, uniform wear, customs and courtesies of the service, small unit tactics, and background information on the role and organization of the Army. Freshman cadets will receive extensive training and practical experience in using a map and compass to navigate cross-country. Sophomore cadets will receive training in First Aid. Additionally, all cadets receive training, and have the opportunity to participate, in several outdoor activities.

Advanced AROTC. Enrollment in the last two years of AROTC is both elective and selective for non-scholarship students. Applicants must demonstrate academic proficiency, leadership ability and officer potential. The Advanced Course builds on the individual skills learned in the Basic Course. During the Junior year (MSIII) cadets receive training in small unit tactics in preparation for their attendance at the AROTC Advanced Camp (normally attended during the summer after their Junior year). Cadets also receive training in management, ethics and leadership, as well as practical experience in performing as the leader in a stressful environment. The senior level (MSIV) cadets receive training on how the Army functions at a higher level by planning and executing many of the Cadet Battalion activities.

AROTC Credit. Military Science credits may be applied to the free elective portion of the degree programs, or used in the Military Science minor program. Military Supplies. Military Science textbooks, uniforms and accessories are issued free of charge to students in the AROTC program. Students enrolled in Advanced Military Science courses also receive a subsistence allowance of \$250 per month for freshmen, \$300 per month for sophomores, \$350 per month for juniors, and \$400 per month for seniors during the regular school year. AROTC Scholarships. The United States Government offers qualified male or female applicants AROTC Scholarships to attend the Colorado School of Mines. AROTC Scholarships pay tuition and fees (within the limits set by the law), provides a book allowance and pay a

subsistence allowance during the school year for the duration of the scholarship. The student may pursue any 4-year degree program offered at CSM. Upon graduation, AROTC Scholarship cadets receive commissions and will be required to serve in the military for four years of an active duty and four years of Reserve Forces duty, for a total of eight years. Individuals interested in applying for AROTC Scholarships should contact high school guidance counselors or the Professor of Military Science, CSM, no later than the first month of the senior year in high school. There are also 2-year and 3-year AROTC Scholarships available to students already in college. A 2-year AROTC Reserve Forces Duty Scholarship is available for cadets entering the Advanced Military Science course who wish to pursue a Reserve Forces military obligation. Another option available to cadets is the Department of the Army Scientific and Engineering AROTC Cooperative Program (DASE AROTC CO-OP). DASE students are hired as Department of the Army civilians. They receive the pay, insurance, sick leave and other benefits provided DA civilian employees. In addition, upon successful completion of the program, students will have the opportunity for continued employment. Qualified students may receive financial assistance of up to \$5,000 per year to cover cost of tuition, books and living expenses.

Navy ROTC (NROTC) Naval Reserve Officer Training Corps

Colorado School of Mines students may pursue a commission as an officer in the U.S. Navy or Marine Corps through a cross town agreement with the Naval ROTC Unit at the University of Colorado, Boulder. NROTC offers two-year and four-year scholarship programs and college (non-scholarship) programs. Navy scholarships may be earned through a national competition based on college board exams and high school record, or while the student is enrolled in college based on college grades and military performance. Scholarship students receive tuition and fees, books, and a \$100 per month subsistence allowance during their last two years in the program (advanced standing).

NROTC students attending Colorado School of Mines must attend a weekly drill session at the University of Colorado Boulder campus and fulfill other military responsibilities. Additionally, they must complete a series of Naval Science courses at the Boulder campus by special arrangement with the appropriate NROTC staff instructor. Navy option students must complete course work in calculus, physics, computer science, American military history or national security policy, and a foreign language. Marine Corps option students are required to complete courses in American military history or national security policy and a foreign language. Students should check with their NROTC class advisor to determine specific course offerings which fulfill the above requirements.

Commissioned Service. The mission of the NROTC program is to provide regular and reserve officers to the fleet and Marine Corps for service in the “Unrestricted Line” fields. Unrestricted Line officers specialize in one of the following: Surface ships, submarines, aviation (Pilot or Naval Flight Officer), Special Warfare (SEALs) or Special Operations (Diving, Salvage, Explosive Ordnance Disposal). Marine Corps officer commissionees enter a variety of fields including infantry, aviation, armor, and combat engineering. Regardless of the type of commission earned, regular or reserve, virtually all NROTC graduates serve on active duty after commissioning. Men and women interested in these and other programs leading to commissions in the Naval Service are encouraged to contact the NROTC Unit at 492-8287 or in person at Folsom Stadium, Gate 6, Room 241, University of Colorado, Boulder.

Air Force ROTC (AFROTC) Air Force Reserve Officer Training Corps

U.S. Air Force ROTC offers several programs leading to a commission in the U.S. Air Force upon receipt of at least a baccalaureate degree.

Standard Four-Year Program

This standard program is designed for incoming freshmen or any student with four years remaining until degree completion. It consists of three parts: the General Military Course (GMC) for lower division (normally freshmen and sophomore) students; the Professional Officer Course (POC) for upper division students (normally juniors and seniors); and Leadership Laboratory (LLAB—attended by all cadets). Completion of a four-week summer training course is required prior to commissioning.

Modified Two-Year Program

All undergraduate and graduate students are eligible for this program. It is offered to full-time, regularly enrolled degree students and requires at least two years of full-time college (undergraduate or graduate level, or a combination). Those selected for this program must complete a six-week field training program during the summer months as a prerequisite for entry into the Professional Officer Course the following fall semester.

Leadership Lab

All AFROTC cadets must attend Leadership Lab (1-1/2 hours per week). The laboratory involves a study of Air Force customs and courtesies, drill and ceremonies, career opportunities, and the life and work of an Air Force junior officer.

Other AFROTC Programs

Other programs are frequently available based on current Air Force needs. Any AFROTC staff member in Boulder (303 492-8351) can discuss best alternatives. Interested students should make initial contact as early as possible to create the best selection opportunity, as selection is on a competitive basis. There is no obligation until a formal contract is entered.

Description of Courses

Freshman Year

*Indicates courses that may be used to satisfy PAGN semester requirements.

*MSGN103. ADVENTURES IN LEADERSHIP I (I)
Development of individual skills necessary to become an effective small group leader. Training is challenging and encompasses a wide variety of skills. A major emphasis is placed on map reading and land navigation principles, including use of the lensatic compass, terrain interpretation, intersection, resection, and magnetic declination. Cadets also receive training in marksmanship, physical training (PT), and military drill, and the Army organization. Lab Fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours.

*MSGN104. ADVENTURES IN LEADERSHIP II (II)
Continuation of MSGN103 training with increased emphasis on leadership. Training also includes small unit tactics, and First Aid training. Lab Fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours.

MSGN198. SPECIAL TOPICS IN MILITARY SCIENCE (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

MSGN199. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Sophomore Year

*MSGN203. ADVENTURES IN LEADERSHIP III (I)
Continues the development of those individual skills taught in MSGN103 and 104. Increased emphasis on the role of the Leader/Trainer. Cadets receive training in First Aid. As with MSGN103, the majority of the training is in the field. Lab Fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours.

*MSGN204. ADVENTURES IN LEADERSHIP IV (II)
In this course emphasis is on development of leadership skills necessary in a small group environment. Students are trained in the mechanics of small unit tactics, the required to perform in various leadership positions. Cadets take an increased role in the planning and execution of cadet activities. Lab Fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours.

MSGN298. SPECIAL TOPICS IN MILITARY SCIENCE (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

Junior Year

MSGN301. APPLIED PRINCIPLES OF LEADERSHIP AND COMMAND I (I) An introduction to the organization of the U.S. Army in the field. Application of leadership principles in the command environment emphasizing motivation, performance counseling, group development, ethics, and attention to detail. Lab Fee. Prerequisite: Enrollment in the AROTC Advanced Course or consent of department. 3 hours lecture; 3 semester hours.

MSGN302. APPLIED PRINCIPLES OF LEADERSHIP AND COMMAND II (II) The theory and practice of small unit tactical operations to include small unit tactics, military problems analysis, communications techniques, and troop leading procedures. Prerequisite: Enrollment in the AROTC Advanced Course or consent of department. Lab Fee. 3 hours lecture; 3 semester hours.

MSGN303. LEADERSHIP LABORATORY (I) Development of military leadership techniques to include preparation of operation plans, presentation of instruction, and supervision of underclass military cadets. Instruction in military drill, ceremonies, and customs and courtesies of the Army. Must be taken in conjunction with MSGN301. Prerequisite: Enrollment in the AROTC Advanced Course or consent of department. Lab Fee. 2 hours lab, 3 hours PT, 80 hours field training; .5 semester hour.

MSGN304. LEADERSHIP LABORATORY (II) Continued development of military leadership techniques with the major emphasis on leading an Infantry Squad. Training is "hands-on." Practical exercises are used to increase understanding of the principles of leadership learned in MSGN302. Must be taken in conjunction with MSGN302. Prerequisite: Enrollment in the ROTC Advanced Course or consent of department. Lab Fee. 2 hours lab, 3 hours PT, 80 hours field training; .5 semester hour.

ADVANCED CAMP (Fort Lewis, WA) A six (6) week Advanced Camp is required for completion of the AROTC program. The camp should be attended between the junior and senior year. The emphasis at Advanced Camp is placed on the development of individual leadership initiative and self-confidence. Students are rated on their performance in various positions of leadership during the camp period. The U.S. Army reimburses students for travel to and from Advanced Camp. In addition, students receive approximately \$600.00 pay while attending camp. Prerequisite: Enrollment in the AROTC Advanced Course and successful completion of MSGN301 through 304.

MSGN398. SPECIAL TOPICS IN MILITARY SCIENCE (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

MSGN399. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

Senior Year

MSGN401. ETHICS, PROFESSIONALISM, AND MILITARY JUSTICE (I) An introduction to military ethics and professionalism with emphasis on the code of the officer. A study of military justice and its application to military life. Orientation to Army administrative, training, and logistics systems. Pre-commissioning orientation. Prerequisite: Enrollment in the AROTC Advanced Course or consent of department. 3 hours lecture; 3 semester hours.

MSGN402. THE AMERICAN MILITARY EXPERIENCE (II) A study of the history of the United States military in order to better understand the role played by the armed forces in American society today through a study of the origins and development of military policy, organization and technology; relating these to political, social and economic development during this period.

MSGN403. LEADERSHIP LABORATORY (I) Continued development of leadership techniques by assignment in the command and staff positions in the Cadet Battalion. Cadets are expected to plan and execute much of the training associated with the day-to-day operations within the cadet battalion. Utilizing the troop leading and management principles learned in previous classes, cadets analyze the problems which the battalion faces, develop strategies, brief recommendations, and execute the approved plan. Lab Fee. Prerequisite: Enrollment in the AROTC Advanced Course or consent of department. 2 hours lab, 1 hour PT, and 80 hours field training; .5 semester hour.

MSGN404. LEADERSHIP LABORATORY (II) Continued leadership development by serving in the command and staff positions in the Cadet Battalion. Cadets take a large role in determining the goals and direction of the cadet organization, under supervision of the cadre. Cadets are required to plan and organize cadet outings and much of the training of underclassmen. Lab Fee. Prerequisite: Enrollment in the AROTC Advanced Course or consent of department. Lab Fee. 2 hours lab, 1 hour PT, and 80 hours field training; .5 semester hour.

MSGN497. SPECIAL STUDIES IN LEADERSHIP AND SMALL GROUP DYNAMICS I (I) The course is specifically geared to the unique leadership challenges faced by individuals involved in CSM student government and other campus leadership positions. Instruction emphasis is on forces and dynamics which shape and define leader/manager's job in the campus environment. Prerequisite: Currently appointed or elected leader of a recognized student organization or consent of the department head. 1 hour lecture and 5 hours lab; 3 semester hours.

MSGN498. SPECIAL TOPICS IN MILITARY SCIENCE (I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours.

MSGN499. INDEPENDENT STUDY (I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours.

(AFROTC)

AFAS100. AFROTC P/T .5 hours

AFAS101. THE AIR FORCE TODAY I This course deals with the US Air Force in the contemporary world through a study of the total force structure, strategic offensive and defensive forces, general purpose forces, aerospace support forces, and the development of communicative skills. 1 hour lecture, 1.5 hours lab; 1.5 semester hour.

AFAS102. THE AIR FORCE TODAY II A continuation of The Air Force Today I. 1 hour lecture, 1.5 hours lab; 1.5 semester hour.

AFAS103. DEVELOPMENT OF AIR POWER I One 1-hour lecture and one 1.5 hour lab per week. This course is designed to examine general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g., Principles of War and Tenets of Air and Space Power. As a whole, this course provides the students with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values with the use of operational examples and historical Air Force leaders and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences. 1 hour lecture, 1.5 hours lab; 1.5 semester hours.

AFAS104. DEVELOPMENT OF AIR POWER II A continuation of DEVELOPMENT OF AIR POWER I. One 1-hour lecture and one 1.5 hour lab per week; 1.5 semester hours.

AFAS105. AIR FORCE MANAGEMENT AND LEADERSHIP I Two 1.5 hour seminars and one 1.5 hour lab per week. This course is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply leadership and management principles of this course. 3 hours lecture, 1.5 hours lab; 3.5 semester hours.

AFAS106. AIR FORCE MANAGEMENT AND LEADERSHIP II A continuation of AIR FORCE MANAGEMENT AND LEADERSHIP I. Two 1.5 hour seminars and 1.5 hour lab per week. 3 hours lecture, 1.5 hours lab; 3.5 semester hours.

AFAS107. NATIONAL SECURITY FORCES IN CONTEMPORARY AMERICAN SOCIETY I Two 1.5 hour seminars and one 1.5 hour lab per week. This course examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership and management principles of this course. 3 hours lecture, 1.5 hours lab; 3.5 semester hours.

Physical Education and Athletics

TOM SPICER, Department Head, Professor and Athletic Director
DIXIE CIRILLO, Assistant Athletic Director
JENNIFER McINTOSH, Athletics Trainer
GREG JENSEN, Assistant Trainer
JEFF SIROVATKA, Assistant Trainer
DAN R. LEWIS, Associate Athletic Director
OSCAR BOES, Cross Country Coach
MARTY HEATON, Assistant Football Coach
JASON KOLTZ, Assistant Football Coach
JASON MUNOZ, Assistant Football Coach
PAULA KRUEGER, Women's Basketball Coach
PRYOR ORSER, Men's Basketball Coach
BOB WRITZ, Golf Coach
DAVID HUGHES, Swimming and Diving Coach
FRANK KOHLENSTEIN, Men's Soccer Coach
MICHAEL MULVANEY, Baseball Coach
MARK ROBERTS, Softball Coach
ROBERT STITT, Football Coach
BRANDON LEIMBACH, Recreational & Club Sports Director
ART SIEMERS, Track Coach
KEITH WILSON, Strength Coach
SHELLY JOHNSON, Volleyball Coach
STEVEN KIMPEL, Wrestling Coach, Physical Education Director

The Department of Physical Education and Athletics offers a four-fold physical education and athletics program which includes (a) required physical education; (b) intercollegiate athletics; (c) intramural athletics; and (d) recreational athletics.

A large number of students use the college's facilities for purely recreational purposes, including swimming, tennis, soccer, basketball, volleyball, weight lifting, softball, and racquetball.

Russell H. Volk Gymnasium

A tri-level complex containing a NCAA regulation swimming pool, a basketball arena, two racquetball/handball courts, wrestling room, weight training facility, locker space, and offices for the Physical Education Department.

Steinhauer Field House

A completely renovated facility of 35,000-sq. ft., which provides for the needs of intercollegiate athletics, physical education classes, intramurals and student recreation.

Baseball Diamond

Located west of Brooks Field and has seating accommodations for 500 spectators.

Softball Field

Located adjacent to the baseball field.

Brooks Field

Named in honor of Ralph D. Brooks, former member of the Board of Trustees of the School of Mines, Brooks Field includes a football/soccer field equipped with lights and a steel-concrete grandstand and bleachers which seat 3,500 spectators.

Tennis Courts

The Department maintains four tennis courts.

Swenson Intramural Complex

Two fields are available for intramural/recreation sports.

Required Physical Education.

Each student at Colorado School of Mines is required to complete four Physical Education classes, beginning with the prerequisite classes of PAGN101 and PAGN102. Four separate semesters of Physical Education is a graduation requirement. Exceptions: (1) a medical excuse verified by a physician; (2) veterans, honorably discharged from the armed forces; (3) entering students 26 years or older or students holding a bachelor's degree. Normally, it is fulfilled during the first two years of attendance. Transfer students should clear with the Admissions Offices regarding advanced standing in physical education. Students who transfer in as freshmen or sophomores without any PA credits will be required to take PAGN101 and PAGN102. Participation in intercollegiate athletics may be substituted for required semesters and hours of physical education. ROTC students can waive the physical education requirement when a similar physical activity is required in their respective ROTC Programs.

Upper-class students who wish to continue taking physical education after completing graduation requirements may re-enroll in any of the regularly scheduled classes on an elective basis.

All students enrolled in physical education shall provide their own gym uniform, athletic shoes, and swimming suit. A non-refundable \$10 fee is assessed for the required locker service. Lockers are also available to students who are not enrolled in physical education classes for the same fee.

Intercollegiate Athletics

The School is a charter member of the Rocky Mountain Athletic Conference (RMAC) and the National Collegiate Athletic Association (NCAA). Sports offered include: football, men's and women's basketball, wrestling, men's and women's track, men's and women's cross country, baseball, men's golf, men's and women's swimming, men's and women's soccer, and women's volleyball and softball. One hour credit is given for a semester's participation in each sport.

Through a required athletic fee, all full-time students attending CSM become members of the CSM Athletic Association, which financially supports the intercollegiate athletic program. With this fee, each CSM student receives free admission to all home athletic events. The Director of Athletics administers this program.

Intramural and Club Sports

The intramural program features a variety of activities ranging from those offered in the intercollegiate athletic program to more recreational type activities. They are governed by the CSM Rec. Sports Council and CSM Sports Club Council. Current offerings may be viewed in the second floor of the Volk Gymnasium on the IM board. All activities are offered in the following categories: Independent men, organizational men, independent women, and co-ed.

The club sport program is governed by the CSM Sport Club Council. There are 29 competitive groups currently under this umbrella. Some teams engage in intercollegiate competition at the non-varsity level, some serve as instructional/recreational entities, and some as strictly recreational interest groups. They are funded through ASCSM. Some of the current organizations are Billiards, Caving, Climbing, Cheerleading, Ice Hockey, Karate, Kendo, Kayak, Judo, Lacrosse, Men's Rugby, Women's Rugby, Shooting, Ski Team, Snowboard, Women's Soccer, Men's Ultimate Frisbee, Women's Ultimate Frisbee, Volleyball, Water Polo.

Description of Courses

All students are required to complete PAGN101 and PAGN102 before they will be allowed to register in higher level activity classes. The only exceptions to this requirement are students enrolled in intercollegiate athletics and ROTC. (See Required Physical Education.)

Freshman Year

PAGN101. PHYSICAL EDUCATION (I) (Required) A general overview of life fitness basics which includes exposure to educational units of Nutrition, Stress Management, Drug and Alcohol Awareness. Instruction in Fitness units provide the student an opportunity for learning and the beginning basics for a healthy life style.

PAGN102. PHYSICAL EDUCATION (II) (Required) Sections in physical fitness and team sports, relating to personal health and wellness activities. Prerequisite: PAGN101 or consent of the Department Head.

Sophomore, Junior, Senior Years

Students may select one of several special activities listed below. Approved transfer credit may be substituted for the following classes:

PAGN201. PERSONAL WELLNESS Provides an overview of the 5 Dimensions of Wellness: Physical, Social, Emotional, Intellectual and Spiritual. Students will take a proactive approach to developing strategies for optimum wellness including goal setting and application of wellness principles through assignments and group in-class work. Prerequisites: PAGN101 and PAGN102 or consent of Department Head. 2 hours lecturer; 1 semester hour.

PAGN205 through PAGN236. (Students enrolling in these courses may be required to furnish their own equipment.)
Prerequisite: PAGN101 or PAGN102 or consent of Department Head. 2 hours activity; .5 semester hour.

PAGN205A. BEGINNING KARATE
PAGN205B/C. INTERMEDIATE/ADVANCED KARATE
PAGN205D/E. YOGA
PAGN205F. JUDO
PAGN209. BEGINNING GOLF (I)
PAGN210. BEGINNING GOLF (II)
PAGN211A. WOMEN'S RACQUETBALL
PAGN211B. BEGINNING RACQUETBALL
PAGN215. TENNIS (I)
PAGN216. TENNIS (II)
PAGN217. CO-ED WEIGHT TRAINING (I)
PAGN217C. WOMEN'S WEIGHT TRAINING
PAGN218. CO-ED WEIGHT TRAINING (II)
PAGN221. BADMINTON (I)
PAGN235. AEROBICS (I)
PAGN235D. WATER AEROBICS
PAGN235E. SWIMMING
PAGN235F/G FLYFISHING
PAGN236. AEROBICS (II)
PAGN301A INTERMEDIATE BASKETBALL
PAGN301B INTERMEDIATE VOLLEYBALL
PAGN310A. WOMEN'S RUGBY

Intercollegiate Athletics

Instruction and practice in fundamentals and mechanics of the selected sport in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Note: All courses shown below, numbered 151 to 182 inclusive are likewise offered as junior, and senior courses. For freshmen and sophomores, they are numbered 151 to 182; juniors and seniors, 351 to 382. Odd numbered courses are offered in the fall, even numbered courses in the spring.

PAGN151. BASEBALL (I)
PAGN152. BASEBALL (II)
PAGN153. BASKETBALL (I) A-men; B-women
PAGN154. BASKETBALL (II) A-men; B-women
PAGN157. CROSS COUNTRY (I)
PAGN159. FOOTBALL (I)
PAGN160. FOOTBALL (II)
PAGN161. GOLF (I)
PAGN162. GOLF (II)
PAGN167. SOCCER (I)
PAGN168. SOCCER (II)
PAGN169. SWIMMING (I)
PAGN170. SWIMMING (II)
PAGN171. TENNIS (I)
PAGN172. TENNIS (II)
PAGN173. TRACK (I)
PAGN174. TRACK (II)
PAGN175. WRESTLING (I)
PAGN176. WRESTLING (II)
PAGN177. VOLLEYBALL (I)
PAGN178. VOLLEYBALL (II)
PAGN179. SOFTBALL (I)
PAGN180. SOFTBALL (II)

Prerequisite: Consent of department. 1 semester hour.

Section 6 - Research Centers and Institutes

Advanced Coatings and Surface Engineering Laboratory

The Advanced Coating and Surface Engineering Laboratory (ACSEL) is a multi-disciplinary laboratory that serves as a focal point for industry-driven research and education in advanced thin films and coating systems, surface engineering, tribology, electronic, optical and magnetic thin films and devices. The laboratory is supported by a combination of government funding agencies (NSF, DOE, DOD) and an industrial consortium that holds annual workshops designed to maximize interaction between participants, evaluate the research conducted by graduate students and faculty, and provide direction and guidance for future activities. ACSEL provides opportunities for CSM faculty and graduate students to visit and work in sponsor facilities, participate in technical meetings with sponsors, and for CSM graduates to gain employment with sponsors.

Advanced Control of Energy and Power Systems

The Advanced Control of Energy and Power Systems Center (ACEPS), based in the Engineering Division, features a unique partnership consisting of industry, the National Science Foundation (NSF), the Department of Energy (DOE), the Electric Power Research Institute (EPRI), Colorado School of Mines (CSM) and twelve other universities. The mission of ACEPS is to conduct fundamental and applied research supporting the technical advancement of the electric utility industry, their customers, and component suppliers in the field of electric power systems and power electronics with special emphasis on the advanced/intelligent control and power quality in the generation, transmission, distribution, and utilization; using such research as a means of advancing graduate education.

Center research projects focus on the development of an intelligent energy system that will employ advanced power electronics, enhanced computer and communications systems, renewable energy applications, and distributed generation. Examples include development of intelligent substations, impact of highly varying loads, power quality, electrical equipment life assessment, and intelligent automatic generation control for transient loads.

Advanced Steel Processing and Products Research Center

The Advanced Steel Processing and Products Research Center (ASPPRC) at Colorado School of Mines was established in 1984. The Center is a unique partnership between industry, the National Science Foundation (NSF), and Colorado School of Mines, and is devoted to building excellence

in research and education in the ferrous metallurgy branch of materials science and engineering. Objectives of ASPPRC are to perform research of direct benefit to the users and producers of steels, to educate graduate students within the context of research programs of major theoretical and practical interest to the steel-using and steel-producing industries, to stimulate undergraduate education in ferrous metallurgy, and to develop a forum to stimulate advances in the processing, quality and application of steel.

Research programs consist of several projects, each of which is a graduate student thesis. Small groups of students and faculty are involved in each of the research programs. Sponsor representatives are encouraged to participate on the graduate student committees.

The Center was established with a five-year grant of \$575,000 from the National Science Foundation, and is now self-sufficient, primarily as a result of industry support.

Center for Automation, Robotics and Distributed Intelligence

The Center for Automation, Robotics and Distributed Intelligence (CARDI) focuses on the study and application of advanced engineering and computer science research in control theory, learning, neural networks, robotics, data mining, image processing, signal processing, sensor fusion, information technology, distributed networks, sensor and actuator development and artificial intelligence to problems in environment, energy, natural resources, materials, transportation, information, communications and medicine. CARDI concentrates on problems which are not amenable to traditional solutions within a single discipline, but rather require a multi-disciplinary systems approach to integrate technologies. The systems require closed loop controllers that incorporate artificial intelligence and machine learning techniques to reason autonomously or in cooperation with a human supervisor.

Established in 1994, CARDI includes faculty from the Division of Engineering, departments of Mathematical and Computer Science, Geophysics, Metallurgical and Materials Engineering, and Environmental Science and Engineering. Research is sponsored by industry, federal agencies, state agencies, and joint government-industry initiatives. Interaction with industry enables CARDI to identify technical needs that require research, to cooperatively develop solutions, and to generate innovative mechanisms for the technology transfer. Enthusiastic and motivated students are encouraged to join CARDI for education and research in the area of robotics and intelligent systems.

Center for Combustion and Environmental Research

The Center for Combustion and Environmental Research (CCER) is an interdisciplinary research and educational unit established by research active faculty with expertise in the chemistry and physics of energy conversion processes. Staff members include faculty, research faculty, post doctoral associates, and graduate students. Funded research projects are varied but fall into 5 core areas: fuel cells, diesel combustion experiments and modeling, materials synthesis in flames, combustion modeling, and optical measurement development for combustion systems and combustion effluent flows. As society's energy needs evolve, it is expected that a sixth area focused on fuels will emerge within the center as well.

Due to the energy conversion focus, collaborative projects typically include CSM's Engineering Division and the Chemical Engineering Department. For further information, contact the center director, Professor Terry Parker of the Engineering Division.

Center for Earth Materials, Mechanics, and Characterization

EM²C is a multidisciplinary research center intended to promote research in a variety of areas including rock mechanics, earth systems, and nontraditional characterization. The Center does not limit its focus to either "hard" or "soft" rock applications but instead fosters research in both arenas and encourages interdisciplinary communication between the associated disciplines. The Colorado School of Mines is a world leader in multidisciplinary integration and therefore presents a unique atmosphere to promote the success of such research. Faculty and students from the Departments of Petroleum Engineering, Geophysical Engineering, Geology and Geological Engineering, Engineering, and Mining Engineering are involved in EM²C. In addition to traditional topics in these disciplines, the center cultivates research in nontraditional characterization such as arctic ice coring, extraterrestrial space boring, and laser/rock destruction for multiple applications. EM²C was established in 2003.

Center for Engineering Education

The Center serves as a focal point for educational research conducted by CSM faculty. Successfully educating tomorrow's scientists and engineers requires that we look at student learning as a system. The principles of cognitive psychology and educational psychology provide the best explanation of how this learning system works. Education will be most effective when educational research, informed by the principles of cognitive and educational psychology, along with the application of that research, and teaching, are linked and interrelated.

The primary goals of the Center for Engineering Education are

- ◆ To conduct world-class research on teaching and learning in science and engineering.
- ◆ To use the results of that research to continually improve instruction at the Colorado School of Mines to better support the learning process of our students.
- ◆ To support the educational needs of science and engineering instructors at the pre-college, college, graduate and professional development levels.

Center for Environmental Risk Assessment

The mission of the Center for Environmental Risk Assessment (CERA) at CSM is to unify and enhance environmental risk assessment research and educational activities at CSM. By bringing diverse, inter-disciplinary expertise to bear on problems in environmental risk assessment, CERA facilitates the development of significantly improved, scientifically-based approaches for estimating human and ecological risks and for using the results of such assessments. Education and research programs within CERA integrate faculty and students from the departments of Chemical Engineering and Petroleum Refining, Environmental Sciences and Engineering, Chemistry and Geochemistry, Mathematics and Computer Science, and Geology and Geological Engineering.

Center for Intelligent Biomedical Devices and Musculoskeletal Systems

The multi-institutional Center for Intelligent Biomedical Devices and Musculoskeletal systems (IBDMS) integrates programs and expertise from CSM and the University of Colorado at Denver and Health Sciences Center. Established at CSM as a National Science Foundation (NSF) Industry/University Cooperative Research Center, IBDMS is also supported by industry, State, and Federal organizations.

IBDMS has become an international center for the development of Computer Assisted Surgery, Advanced Orthopaedic Applications, Sports Medicine, Occupational Biomechanics, and Biomaterials. Through the efforts of this center, new major and minor programs in bioengineering and biotechnology are being established at both the CSM graduate and undergraduate levels.

IBDMS seeks to establish educational programs in addition to short- and long-term basic and applied research efforts that would enhance the competitive position of Colorado and U.S. bio-industry in the international markets. IBDMS focuses the work of diverse engineering, materials and medicine disciplines. Its graduates are a new generation of students with an integrated engineering and medicine systems view, with increasing opportunities available in the biosciences.

For more information about the IBDMS Center please contact Dr. Joel M. Bach at jmbach@mines.edu or 303-384-2161.

Center for Research on Hydrates and Other Solids

Since 1975, the Center for Research on Hydrates and Other Solids has performed both fundamental and applied research on natural gas hydrates, curious ice-like compounds composed of water and hydrocarbon gases. Gas hydrates, which generally form at cold temperatures and high pressures, present both a major challenge and major opportunity in energy production. Gas hydrates can plug deep sea and arctic gas and oil pipelines, and preventing hydrate formation is a major design and operational challenge. On the other hand, naturally occurring gas hydrates could potentially provide the world's largest resource of natural gas. Recently, researchers at the center have also found that hydrates can be used a hydrogen storage material, for potential use in fuel cell vehicles.

With active participation of faculty, graduate, and undergraduate students, the center provides a unique combination of expertise that has enabled CSM to achieve international prominence in gas hydrate research. CSM participants interact on an on-going basis with sponsors and other collaborators, including frequent visits to their facilities both in the US and abroad. For students, this interaction often continues beyond graduation, with opportunities for employment at sponsoring industries. More information can be found at the center website, www.mines.edu/research/chs.

Center for Solar and Electronic Materials

The Center for Solar and Electronic Materials (CSEM) was established in 1995 to focus, support, and extend growing activity in electronic materials for solar applications, in electronic and microelectronic technologies, and in related optical technologies. In addition to photovoltaics, CSEM supports research into advanced optics, novel optical devices, thin film materials, polymeric devices, micro fluidic devices, nanoscale science and nanofabrication, novel characterization, electronic materials processing, process simulation, and systems issues associated with electronic materials and devices. Alternative energy technologies and sustainability are also areas of interest. CSEM facilitates interdisciplinary collaborations across the CSM campus and fosters interactions with national laboratories, industries, public utilities, local state and federal government, and other universities. The center coordinates grant applications by its members to collective funding opportunities, manages a joint-use laboratory with a broad range of characterization and processing tools, purchases joint-use tools based on member needs and maintains a virtual computational lab. In fulfilling its research and educational mission, CSEM draws from expertise in the departments of Physics, Chemical Engineering, Metallurgical and Materials Engineering, Chemistry and Geochemistry, and from the Division of Engineering.

CSEM also serves to guide and strengthen the curriculum in electronic materials and related areas. CSEM members develop and teach relevant courses. CSEM also emphasizes training through research experiences for both graduate and undergraduate students. Graduate students in the above-mentioned departments as well as the materials science program can pursue research on center-related projects. Undergraduates are involved through engineering design courses and summer research experiences. Close proximity to the National Renewable Energy Lab and several local photovoltaic companies provides a unique opportunity for students to work with industry and government labs as they solve real world problems. External contacts also provide guidance in targeting the educational curriculum toward the needs of the electronic materials industry.

Center for Space Resources (CSR)

The Center for Space Resources is dedicated to the human and robotic exploration of space and to the utilization of what we learn to the improvement of our society by developing technologies for space resource extraction, manufacturing in space, and life-support systems on spacecraft and planetary habitats. While there are several practical applications of space exploration on Earth, the greatest achievement bringing benefits to humankind would be to develop commercial applications of space technology, including space and planetary resources, in space.

These will one day form the basis for new space industries that include the harvesting of solar energy outside Earth's atmosphere, the development of an in-space reusable transportation infrastructure carrying payloads from Earth to geostationary orbits, the Moon or Mars and back, servicing of satellites to extend their useful lifetimes and reduce the costs of space operations, and processing of value-added materials in Earth orbit based on lunar material resources.

These goals are pursued by a Consortium involving faculty and students from several departments, NASA and other government agencies, and industrial partners working together on space-related projects.

Center for Wave Phenomena

With sponsorship for its research by 24 companies in the worldwide oil exploration industry and several government agencies, this program, which includes faculty and students from the Departments of Geophysics, is engaged in a coordinated and integrated program of research in wave propagation, inverse problems and seismic data processing. Its methods have applications to seismic exploration and reservoir monitoring, global seismology, nondestructive testing and evaluation, and land-mine detection, among other areas. Extensive use is made of analytical methods as well as computational techniques. Methodology is developed through computer implementation, based on the philosophy that the

ultimate test of an inverse method is its application to experimental data. Thus, the group starts from a physical problem, develops a mathematical model that adequately represents the physics, derives an approximate solution, generates a computer code to implement the method, performs tests on synthetic data, and finally, on field data.

Center for Welding, Joining and Coatings Research

The Center for Welding, Joining and Coatings Research (CWJCR) is an interdisciplinary organization with researchers and faculty from the Metallurgical and Materials Engineering Department, the Engineering Division, and the Mining Engineering Department. The goal of CWJCR is to promote education and research, and to advance understanding of the metallurgical and processing aspects of welding, joining and coating processes. Current center activities include: education, research, conferences, short courses, seminars, information source and transfer, and industrial consortia. The Center receives significant support from industry, national laboratories and government entities.

The Center for Welding, Joining and Coatings Research strives to provide numerous opportunities that directly contribute to the student's professional growth. Some of the opportunities include:

- Direct involvement in the projects that constitute the Center's research program.
- Interaction with internationally renowned visiting scholars.
- Industrial collaborations that provide equipment, materials and services.
- Research experience at industrial plants or national laboratories.
- Professional experience and exposure before nationally recognized organizations through student presentations of university research.
- Direct involvement in national welding, materials, and engineering professional societies.

Chevron Center of Research Excellence

The Chevron Center of Research Excellence (CoRE) is a partnership between the Colorado School of Mines (CSM) and Chevron (CVX) to conduct research on sedimentary architecture and reservoir characterization and modeling. The center supports the development of new earth science technology while providing CVX international employees the opportunity to earn advanced degrees.

Colorado Center for Advanced Ceramics

The Colorado Center for Advanced Ceramics (CCAC) is developing the fundamental knowledge that is leading to important technological developments in advanced ceramics and composite materials. Established at CSM in April 1988 as a

joint effort between CSM and the Coors Ceramics Company (now CoorsTek), the Center is dedicated to excellence in research and graduate education in high technology ceramic and composite materials. The goal of the Center is to translate advances in materials science into new and improved ceramic fabrication processes and ceramic and composite materials. Current research projects cover a broad spectrum of materials and phenomena including porous ceramics and metals for filters; nano-scale powder preparation and mechanics; ceramic-metal composites; fuel cell, solar cell and battery materials; high temperature gas and plasma corrosion; interparticle forces; structure of grain boundaries; and mechanical properties of thin films. Current projects are supported by both industry and government and several students are performing their research through a collaboration with the National Renewable Energy Laboratory located in Golden. Each project involves research leading to a graduate thesis of a student.

Colorado Energy Research Institute

Originally established in 1974 and reestablished in 2004, the Colorado Energy Research Institute (CERI) promotes research and educational activities through networking among all constituencies in Colorado, including government agencies, energy industries, and universities. CERI's mission is to serve as a state and regional resource on energy and energy-related minerals issues, provide energy status reports, sponsorship of symposia, demonstration programs, and reports on research results. CERI's activities enhance the development and promotion of energy and energy-related minerals education programs in the areas of energy development, utilization, and conservation, and provide a basis for informed energy-related state policies and actions.

Colorado Institute for Fuels and Energy Research

The Colorado Institute for Fuels and Energy Research (CIFER) is an interdisciplinary research institute involving faculty and students from several academic departments at the Colorado School of Mines. CIFER originally was formed to assist industry, State and Federal governments in developing and implementing clean air policy for the benefit of the U.S. and particularly for high altitude communities through the development of newer, cleaner burning fuels and the technology to properly use fuels. It has evolved to include a substantial component of combustion and fuel cell research as well as energy related computational modeling.

Colorado Institute for Macromolecular Science and Engineering

The Colorado Institute for Macromolecular Science and Engineering (CIMSE) was established in 1999 by an interdisciplinary team of faculty from several CSM departments. It is sponsored by the National Science Foundation, the Environmental Protection Agency, the United States Department of Agriculture, and the Department of Energy.

The mission of the Institute is to enhance the training and research capabilities of CSM in the area of polymeric and other complex materials as well as to promote education in the areas of materials, energy, and the environment.

Fourteen CSM faculty members from eight departments are involved with the Institute's research. The research volume is more than \$1 million and supports around 15 full-time graduate students in polymers, nanotechnology, colloids, microfluidics, and complex fluids. Current research projects include plastics and nanocomposites from renewable resources, novel methods for synthesizing polymers and self-assembling nanostructures, microfluidic flow manipulation for chemical and biological separations, and theory and computational study of complex matter.

CIMSE works to improve the educational experience of undergraduate and graduate students in polymers and complex fluids as well as to maintain state-of-the-art facilities. The science and engineering of materials is a core competency of CSM, and CIMSE will play an important role in ensuring that our students remain competitive.

Energy and Minerals Field Institute

The Energy and Minerals Field Institute is an educational activity serving Colorado School of Mines students and external audiences. The goal of the Institute is to provide better understanding of complex regional issues surrounding development of western energy and mineral resources by providing firsthand experience that cannot be duplicated in the classroom. The Institute conducts field programs for educators, the media, government officials, industry, and the financial community. The Institute also hosts conferences and seminars throughout the year dealing with issues specific to western resources development. Students involved in Institute programs are afforded a unique opportunity to learn about the technological, economic, environmental, and policy aspects of resource development.

Excavation Engineering and Earth Mechanics Institute

The Excavation Engineering and Earth Mechanics Institute (EMI), established in 1974, combines education and research for the development of improved excavation technology. By emphasizing a joint effort among research, academic, and industrial concerns, EMI contributes to the research, development and testing of new methods and equipment, thus facilitating the rapid application of economically feasible new technologies.

Current research projects are being conducted throughout the world in the areas of tunnel, raise and shaft boring, rock mechanics, micro-seismic detection, machine instrumentation and robotics, rock fragmentation and drilling, materials handling systems, innovative mining methods, and mine design and economics analysis relating to energy and non-fuel minerals development and production. EMI has been a pioneer in the development of special applications software and

hardware systems and has amassed extensive databases and specialized computer programs. Outreach activities for the Institute include the offering of short courses to the industry, and sponsorship and participation in major international conferences in tunneling, shaft drilling, raise boring and mine mechanization.

The full-time team at EMI consists of scientists, engineers, and support staff. Graduate students pursue their thesis work on Institute projects, while undergraduate students are employed in research.

International Ground Water Modeling Center

The International Ground Water Modeling Center (IGWMC) is an information, education, and research center for ground-water modeling established at Holcomb Research Institute in 1978, and relocated to the Colorado School of Mines in 1991. Its mission is to provide an international focal point for ground-water professionals, managers, and educators in advancing the use of computer models in ground-water resource protection and management. IGWMC operates a clearinghouse for ground-water modeling software; organizes conferences, short courses and seminars; and provides technical advice and assistance related to ground water. In support of its information and training activities, IGWMC conducts a program of applied research and development in ground-water modeling.

Kroll Institute for Extractive Metallurgy

The Kroll Institute for Extractive Metallurgy (KIEM), a Center for Excellence in Extractive Metallurgy, was established at the Colorado School of Mines in 1974 using a bequest from William J. Kroll. Over the years, the Kroll Institute has provided support for a significant number of undergraduate and graduate students who have gone on to make important contributions to the mining, minerals and metals industries. The initial endowment has provided a great foundation for the development of a more comprehensive program to support industry needs.

The primary objectives of the Kroll Institute are to provide research expertise, well-trained engineers to industry, and research and educational opportunities to students, in the areas of minerals, metals and materials processing; extractive and chemical metallurgy; chemical processing of materials; and recycling and waste treatment and minimization.

Marathon Center of Excellence for Reservoir Studies

Marathon Center of Excellence for Reservoir Studies conducts collaborative research on timely topics of interest to the upstream segment of the petroleum industry and provides relevant technical service support, technology transfer, and training to the Center's sponsors. Research includes sponsorship of M.S. and Ph.D. graduate students, while technology transfer and training involve one-on-one training of practi-

ing engineers and students from the sponsoring companies. The Center is a multi-disciplinary organization housed in the Petroleum Engineering Department. The Center activities call for the collaboration of the CSM faculty and graduate students in various engineering and earth sciences disciplines together with local world-class experts. The Center was initiated with a grant from Marathon Oil Company in 2003 and has been serving the oil industry around the world. The current research topics include: reservoir engineering aspects of horizontal and deviated wells, Non-Darcy flow effects in hydraulic fractures and naturally fractured reservoirs, streamline modeling in dual-porosity reservoirs, multi-scale simulation methods to capture the fine-scale heterogeneity effects in displacement processes, modeling of transient flow in hydraulically fractured horizontal wells, naturally fractured reservoirs containing multiple sets of intersecting fractures, numerical modeling of reservoirs containing sparse naturally fractured regions, improved modeling of matrix vertical flow in dual-porosity reservoirs, steam assisted gravity drainage (SAGD) for medium gravity foamy oil reservoirs.

Petroleum Exploration and Production Center

The Petroleum Exploration and Production Center (PEPC) is an interdisciplinary educational and research organization specializing in applied studies of petroleum reservoirs. The center integrates disciplines from within the Departments of Geology and Geological Engineering, Geophysics and Petroleum Engineering.

PEPC offers students and faculty the opportunity to participate in research areas including: improved techniques for exploration, drilling, completion, stimulation and reservoir evaluation techniques; characterization of stratigraphic architecture and flow behavior of petroleum reservoirs at multiple scales; evaluation of petroleum reserves and resources on a national and worldwide basis; and development and application of educational techniques to integrate the petroleum disciplines.

Reservoir Characterization Project

The Reservoir Characterization Project (RCP), established in 1985 at Colorado School of Mines, is an industry-sponsored research consortium. Its mission is to develop and apply 4-D, 9-C seismology and associated technologies for enhanced reservoir recovery. Each multi-year research phase focuses on a consortium partner's unique field location, where multi-component seismic data are recorded, processed and interpreted to define reservoir heterogeneity and architecture. Each field study has resulted in the development and advancement of new 3- and 4-D multicomponent acquisition, processing, and interpretation technology, which has led to additional hydrocarbon recovery. Research currently focuses on dynamic reservoir characterization, which enables monitoring of the reservoir production process.

The Reservoir Characterization Project promotes interdisciplinary research and education among industry and students in the fields of geophysics, geology and geological engineering, and petroleum engineering.

Section 7 - Services

Arthur Lakes Library

Arthur Lakes Library is a regional information center for engineering, energy, minerals and materials science, and associated engineering and science fields. The library provides educational and research resources to support and enhance the academic mission of CSM. The library staff is committed to excellence in supporting the information needs of the CSM community and providing access to information for library users.

The library collections include more than 500,000 volumes; approximately 1800 serial titles with hundreds of databases and e-journals; over 201,000 maps; archival materials on CSM 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, including selected NTIS publications.

Access to CSM collections is provided by Catalyst, the on-line public access catalog and circulation system. Students and faculty have access to nearly all of the library's electronic resources from any computer on the campus network, including those in networked CSM residential facilities. Dial-up and Internet access is also available from on and off-campus. See the library's web page at <http://www.mines.edu/library/> for more information and Web links.

Reference resources include specialized electronic databases, websites and print indexes. Reference librarians provide instruction and personal help as needed, conduct library research sessions for classes, and provide e-mail and telephone reference and research services.

In addition to material that can be checked out from the CSM library and other libraries within the Colorado Alliance, interlibrary loan service provides access to materials from regional and world-wide libraries.

Academic Computing and Networking

Please note that all Academic Computing and Networking facility offices and labs currently located in the Green Center are expected to move to the CTLM addition sometime during the 2006-2007 academic year. Please check with AC&N staff if you have questions about this relocation.

Academic Computing and Networking (AC&N) provides computing and networking services to meet the instructional, research, and networking infrastructure needs of the campus. AC&N manages and operates the campus network along with central academic computing systems and laboratories located in the Green Center, CTLM, Writing Center, and Library. In addition, AC&N's academic department support services group provides support services for many departmental servers, laboratories, and desktops.

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://www.mines.edu/academic/computer/>, directly from the front desk of the Computing Center (Green Center 231) or CTLM locations, 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 provided to the campus community include e-mail, wired and wireless network operation and support, modem pools, access to the commodity Internet, Internet 2, and National Lambda Rail, network security, volume and site licensing of software, on-line training modules, videoconferencing, and campus web site and central systems administration and support. In addition, support and administration is provided for some academic department servers, laboratories, and desktops. AC&N manages and supports the central course management system (Blackboard), calendaring services, 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 AC&N and many 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 posted at <http://www.mines.edu/academic/computer/policies/>. For more information about AC&N, see the web pages at <http://www.mines.edu/academic/computer/>.

Copy Center

Located on the first floor of Guggenheim Hall, the Copy Center offers on-line binding, printed tabs, and halftones. Printing can be done on all paper sizes from odd-sized originals. Some of the other services offered are GBC and Velo Binding, folding, sorting and 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

(CSMAA) The Colorado School of Mines Alumni Association, established in 1895, serves the Colorado School of Mines and its alumni. Services and benefits of membership include:

Mines, a quarterly publication covering campus and alumni news; an online directory of all Mines alumni for networking purposes; on-line job listings; section activities that provide social and networking connections to the campus and other Mines alumni around the world; invitations to local and annual alumni meetings, reunions, golf tournaments and other special events on and off campus; awards, including the opportunity to nominate outstanding fellow alumni and be nominated yourself; CSM library privileges for Colorado residents; access to career service aids; discounts with partner vendors; and e-mail forwarding services.

Benefits for current Colorado School of Mines students are legacy grants for children or grandchildren of alumni; the Student Financial Assistance Program; recognition banquets for graduating seniors/graduate students; the CSMAA Mentorship program, pairing students with alumni for professional development; assistance and support of School events such as Homecoming; alumni volunteer assistance in student recruiting; Order of the Engineer ceremonies; and programs enabling alumni input in school programming.

For further information, call 303 273-3295, FAX 303 273-3583, e-mail csm@mines.edu, or write Mines Alumni Association, 1600 Arapahoe Street, 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 195. 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.

Green 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.

Bunker Memorial Auditorium, which seats 1,386, has a large stage that may be used for lectures, concerts, drama productions, or for any occasion when a large attendance is expected.

Friedhoff Hall contains a dance floor and an informal stage. Approximately 600 persons can be accommodated at tables for banquets or dinners. Auditorium seating can be arranged for up to 450 people.

Petroleum Hall and Metals Hall are lecture rooms seating 123 and 310, respectively. Each room has audio visual equipment. In addition, the Green Center houses the modern Computing Center and the Department of Geophysics.

INTERLINK Language Center (ESL)

The INTERLINK Language program combines intensive English language instruction (ESL) with academic training and cultural orientation to prepare students for their studies at CSM. Designed for international students in engineering and the sciences, the program prepares students for a successful transition to their new academic and cultural environment. The curriculum focuses on individual student needs, utilizing experiential learning projects, media technology (video, film, computers, TV, radio, the Internet) and various sources and resources in the surrounding community. Successful completion of the program may entitle academically qualified students to begin their academic studies without a TOFEL score.

The program is open to adults who have completed secondary school in good standing (grade point average of C+ or above) and are able to meet their educational and living expenses. For further information contact INTERLINK Language Center (ESL) at:

INTERLINK Language Center (ESL)
Colorado School of Mines, Golden, CO 80401
<http://www.eslus.com>
<http://www.mines.edu/Outreach/interlink>
Email: interlinkcsm@mines.edu
Tele: 303-273-3516
Fax: 303-278-4055

LAIS Writing Center

Located in room 311 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 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/Academic/lais/wc/writingcenter.html>).

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 con-

cerning 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 109 Stratton Hall. For more specific information about study abroad and other international programs, contact OIP at 384-2121 or visit the OIP web page (<http://www.mines.edu/Academic/lais/OIP/>).

The office works with the departments and divisions of the School to: (1) help develop and facilitate study abroad opportunities for CSM students while serving as an informational and advising resource for them; (2) assist in attracting new international students to CSM; (3) serve as a resource for faculty and scholars of the CSM community, promoting faculty exchanges, faculty-developed overseas learning opportunities, 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, helps promote the internationalization of CSM's curricular programs and activities. OIP promotes and coordinates the submission of Fulbright, Rhodes, Churchill and Marshall Scholarship programs on campus.

Office of Technology Transfer

The purpose of the Office of Technology Transfer (OTT) is to reward innovation and entrepreneurial activity by students, faculty and staff, recognize the value and preserve ownership of CSM's intellectual property, and contribute to Colorado's and the nation's economic growth. OTT reports directly to the CSM President, and the office works closely with the Vice President of Research and Technology Transfer and the School's Office of Legal Services to coordinate activities. Through its internal technical review team and external business commercialization 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) Generate a new source of revenue for CSM to expand the school's research and education.

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 of Women in Science, Engineering and Mathematics, Colorado School of Mines, 1133 17th Street, Golden, CO 80401-1869, or call (303) 273-3097; dlasich@mines.edu or <http://www.mines.edu/Academic/affairs/wisem/>.

Public Relations

The communications staff in the President's Office is responsible for public relations and marketing initiatives at Mines. For information about the School's publications guidelines, including the use of Mines logos, and for media-related requests, contact Marsha Williams, Director of Integrated Marketing Communications, 303-273-3326 or marswill@mines.edu.

Research Services

The Office of Research Services (ORS), under the Associate Vice President for Finance and Operations and Controller, 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/ors.

Special Programs and Continuing Education (SPACE)

The SPACE Office offers 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 Mine Safety and Health Training Program. A separate bulletin lists the educational programs offered by the SPACE Office, CSM, 1600 Arapahoe St., Golden, CO 80401. Phone: 303 273-3321; FAX 303 273-3314; email space@mines.edu; website www.mines.edu/Outreach/Cont_Ed.

Telecommunications

The Telecommunications Office is located at the west end of the Plant Facilities building, and provides telephone services to the Campus. The Telecommunications Office also maintains a CSM Campus Directory in conjunction with the Information Services department available anytime to faculty, staff, and students on the Web at www.mines.edu/directory.

Local telephone service is provided, as part of the housing rates (optional for Mines Park residence). The Telecommunications Office provides maintenance for telephone lines and services. Students will need to bring or purchase their own calling line ID device if they choose to take advantage of this feature.

The Telecommunications Office provides long distance services for the Residence Halls, Sigma Nu house, Fiji house, PI PHI House, ALPHA PHI House, SIGMA KAPPA House and Mines Park housing areas through individual account codes. Long distance rates for domestic calling are 0.05 cents per minute, 24 hours a day, seven days a week. International rates are available at the Telecommunications Office or through the Web at <http://www.is.mines.edu/telecomm/Students/StudRate.asp>. Accounts are issued by request at any time. Monthly long distance charges are assessed to the student accounts by the 5th of each month for calls made the prior month, and invoices are mailed directly to students at their campus address. Questions regarding the above services should be directed to the Telecommunications Office by calling (303) 273-3000 or 1-800-446-9488 and saying Telecommunications, or via the Web at <http://www.is.mines.edu/telecomm/>.

Directory of the School

BOARD OF TRUSTEES

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JUSTIN CHICHESTER Student Representative

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ADMINISTRATION

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NIGEL T. MIDDLETON, 1990-B.Sc., Ph.D., University of the Witwatersrand, Johannesburg; Executive Vice President for Academic Affairs and Dean of Faculty; Professor of Engineering, P.E., S. Africa
HAROLD R. CHEUVRONT, 1976-84, 1985-B.S., M.A., West Virginia University; Ph.D., University of Northern Colorado; Vice President for Student Life and Dean of Students

PETER HAN, 1993-A.B., University of Chicago; M.B.A., University of Colorado; Vice President for Institutional Advancement
JOHN POATE, 2006-B.S., M.S., Melbourne University; M.A., Ph.D., Australian National University; Vice President for Research and Technology Transfer
ARTHUR B. SACKS, 1993-B.A., Brooklyn College; M.A., Ph.D., University of Wisconsin-Madison; Associate Vice President for Academic and Faculty Affairs; Professor of Liberal Arts and International Studies
BARBARA M. OLDS, 1984-B.A., Stanford University; M.A., Ph.D., University of Denver; Associate Vice President for Educational Innovation; Professor of Liberal Arts and International Studies
THOMAS M. BOYD, 1993-B.S., M.S., Virginia Polytechnic Institute and State University; Ph.D., Columbia University; Dean of Graduate Studies; Associate Professor of Geophysics
LORING ABEYTA, 2006-B.A., University of Denver; M.A., St. Thomas Seminary; Ph.D., University of Denver, Interim Principal Tutor and Program Director, Guy T. McBride, Jr. Honors Program
SARAH ANDREWS, 2005-B.S., Indiana University, Assistant Director of Admissions
LINDA J. BALDWIN, 1994-B.S., Iowa State University; Continuing Education Program Coordinator
GEOFFREY B. BARSCH, 2004-B.S., Colorado State University; Director, Budget and Planning
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GARY L. BAUGHMAN, 1984-B.S.Ch.E., Ohio University; M.S., Ph.D., Colorado School of Mines; Director of Special Programs and Continuing Education
DAVID G. BEAUSANG, 1993-B.S., Colorado State University; Computing Support Specialist
HEATHER BOYD, 1990-B.S., Montana State University; M.Ed., Colorado State University; Senior Assistant Director of Admissions
RICHARD M. BOYD, 2000-B.S., Regis University; Director of Public Safety
RONALD L. BRUMMETT, 1993-B.A., Metropolitan State College; M.A., University of Northern Colorado; M.B.A., University of Colorado Denver; Director of CSM Career Center and the Office for Student Development and Academic Services
TIMOTHY W. CAKE, 1994-B.S., Colorado State University; M.S., Regis University; Director of Plant Facilities

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JENNIFER DOANE, 2005-B.A., Colorado State University, M.A., University of Colorado, Colorado Springs; Assistant Director of Student Activities

MICHAEL DOUGHERTY, 2003-B.A., Cumberland College; M.B.A., University of Alaska Anchorage; Director of Human Resources

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KELLY FOX, 2004-B.A., University of Nebraska; M.P.A., University of Colorado; Director of Policy, Planning and Analysis

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BRUCE P. GOETZ, 1980-84, 1987- B.A., Norwich University; M.S., M.B.A., Florida Institute of Technology; Director of Admissions

SHARON HART, 1999-B.S., Colorado School of Mines; M.A., University of Colorado; Director of Institutional Research

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EVE JORDAL, 2000-Executive Assistant to the Vice President for Student Life and Dean of Students

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DAVID LARUE, 1998-B.A., St. Thomas Seminary College; M.A., University of Colorado at Denver; Ph.D., University of Colorado at Boulder; Computer Support Specialist

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MICHAEL McGUIRE, 1999-Engineer of Mines, Colorado School of Mines; Program Coordinator, Mine Safety and Health Program

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MARY MITTAG-MILLER, 1998-Director of the Office of Research Services

DANIEL MONTEZ, 2003-B.S., University of Northern Colorado; M.S., University of Colorado at Denver; Associate Vice President for Finance and Operations

DEREK MORGAN, 2003- B.S., University of Evansville; M.S., Colorado State University; Director of Student Activities

DAVID MOSCH, 2000-B.S., New Mexico Institute of Mining and Technology; Edgar Mine Manager

DAG NUMMEDAL, 2004-B.A., M.A., University of Oslo; Ph.D., University of Illinois; Executive Director of the Colorado Energy Research Institute

ANITA PARISEAU, 2004-B.S., Ithaca College; Director of Alumni Relations/Executive Director CSM Alumni Association

TRICIA DOUTHIT PAULSON, 1998-B.S., Colorado School of Mines; Associate Registrar

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ANGIE REYES, 1997-B.A., Chadron State College; Student System Manager.

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SANDRA SIMS, 2004-B.S., Pennsylvania State University, M.S., Florida Institute of Technology, PsyD, Florida Institute of Technology; Counselor

THOMAS E. SPICER, 2004-B.S., Fort Hays State University; M.S., Fort Hays State University; Director of Athletics and Head of Physical Education Department

KRISTIN STOLSMARK, 2005-B.A., Dakota State University; Campus ID Card Manager

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CAROL L. WARD, 1993-B.S., Ohio State University; M.A., Denver University; Computer Support Engineer

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ED ZUCKER, 2001-B.A., M.S., University of Arizona; Computing Services Support Manager

EMERITI

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JAMES T. BROWN, B.A., Ph.D., University of Colorado;
Emeritus Professor of Physics

W. REX BULL, B.Sc., App. Diploma in Mineral Dressing,
Leeds University; Ph.D., University of Queensland; Emeritus
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Policies and Procedures

Policies and Procedures

Affirmative Action

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.

Any person feeling that a violation of the following policies has occurred should promptly refer the matter to the Office of Human Resources, located in Guggenheim Hall (2nd floor), for investigation.

Colorado School of Mines 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. (1998) in order to set forth a policy concerning unlawful discrimination at CSM. This policy shall supersede any previously promulgated CSM policy which 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, and military veteran status is prohibited. No discrimination in admission, application of academic standards, financial aid, scholastic awards, promotion, salary, benefits, 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.

III. Persons Who May File an Unlawful Discrimination Complaint

An unlawful discrimination complaint may be filed by any individual described in one of the categories below:

A. Any member of the CSM community, including classified staff, exempt employees, and students as well as any applicant for employment or admission, who believes that he or she has been discriminated against by CSM, a branch of CSM, or another member of the CSM community on account of age, gender, race, ethnicity, religion, national origin, disability, or military veteran status;

B. Any person who believes that he or she has been threatened with or subjected to duress or retaliation by CSM, a branch of CSM, or a member of the CSM community as a result of (1) opposing any unlawful discriminatory practice;

(2) filing a complaint hereunder; (3) representing a Complainant hereunder; or (4) testifying, assisting, or participating in any manner in an investigation, proceeding, hearing, or lawsuit involving unlawful discrimination; or

C. The Human Resources Director or an attorney from the Office of Legal Services, if any of these individuals deem it to be in the best interest of CSM to do so.

IV. Informal Complaint Resolution Process

At the written request of an individual who has come forward with a complaint alleging unlawful discrimination, hereinafter the "Complainant," the Human Resources Director shall assist in an attempt to resolve the complaint in an informal manner. The informal unlawful discrimination complaint resolution process shall consist of an informal discussion between the Complainant and the individual or a representative of the entity accused of unlawful discrimination, hereinafter the "Respondent." The Human Resources Director shall act as a mediator during this process, which shall be calculated to bring the complaint to the attention of the Respondent and elicit the voluntary cooperation of the Respondent in settling the matter. By attempting to resolve the unlawful discrimination complaint in an informal manner pursuant to the terms of this section, the Complainant shall not waive any rights to subsequently pursue the complaint through the formal complaint procedure set forth below.

V. Formal Complaint Procedure

A. Purpose

The purpose of the formal unlawful discrimination complaint procedure is to provide a formal mechanism for the prompt and fair internal resolution of complaints alleging unlawful discrimination. The procedure outlined below shall be the exclusive forum for the internal resolution of such complaints at CSM.

B. Where to file a Complaint

All complaints by non-students alleging unlawful discrimination or retaliation shall be filed in writing at the Office of Human Resources located on the second floor of Guggenheim Hall. Complaints by students alleging unlawful discrimination or retaliation may be submitted to the Human Resources Office, the Student Development Center, the Dean of Students, any faculty member, or any Resident Assistant. Any recipient of such a student complaint shall promptly forward the complaint to the Director of Human Resources for handling in accordance with the provisions set forth below.

C. Time Limits

All complaints alleging unlawful discrimination or retaliation must be filed within ninety days from the date upon which the incident, occurrence, or other action alleged to constitute unlawful discrimination or retaliation occurred. However, if the alleged discrimination or retaliation is of a continuing nature, a complaint may be filed at any time.

D. Contents of Complaint

A complaint alleging unlawful discrimination or retaliation must be signed by the Complainant and set forth specific factual matters believed to constitute unlawful discrimination or retaliation. The complaint shall name as Respondent the individual or entity whom the Complainant believes to have committed, participated in, or encouraged the discrimination or retaliation. The complaint shall also include a brief statement describing the relief requested by the Complainant.

E. Fulfillment of Complaint Prerequisites

As soon as practicable after receipt of a complaint, the Human Resources Director shall submit the complaint to an attorney from the Office of Legal Services, who shall examine it and determine if the prerequisites outlined above have been fulfilled. If the prerequisites have not been fulfilled, the attorney shall inform the Complainant of the specifics of such determination in writing. Unless the time limitations set forth above have lapsed prior to the initial filing of the complaint, the Complainant shall have the opportunity to correct any deficiencies and re-file the complaint. If the prerequisites have been fulfilled, the complaint will be handled as set forth below.

F. Choice of Remedies

No Complainant shall be permitted to simultaneously file an unlawful discrimination claim under the CSM Unlawful Discrimination Policy and Complaint Procedure and a sexual harassment claim under the CSM Sexual Harassment Policy and Complaint Procedure against the same individual arising out of an identical set of facts. In such a situation, a Complainant shall be entitled to file his or her claim under either, but not both, of the above-mentioned policies.

VI. Pre-Hearing Procedures

A. Notification to Proceed

As soon as practicable after a determination has been made that the complaint is sufficient pursuant to subsection V.E above, the reviewing attorney shall inform the Director of Human Resources of that fact and the Director of Human Resources shall proceed with the notifications specified in subsection B below.

B. Acknowledgment of Complaint and Notification of Respondent

As soon as practicable, the Director of Human Resources shall send a letter to the Complainant acknowledging receipt of the complaint. At the same time, the Director shall provide the Respondent with a copy of the complaint and notify the Respondent in writing of the requirements set forth in subsection C below.

C. Response to Complaint

Within ten days from the date of receipt of a copy of the complaint, the Respondent shall file with the Director of Human Resources a response in which the allegations contained in the complaint are admitted or denied. The Director shall provide the Complainant with a copy of the response as soon as practicable. If the response contains a denial of one or

more of the allegations contained in the complaint, the process shall proceed with the selection of a hearing panel as set forth in subsection D below. If no timely response is received, or if the response admits the allegations in their entirety, the matter shall be submitted to the President, who shall then issue a decision in accordance with subsection IX.D below.

D. Selection of Hearing Panel

An initial hearing panel of six individuals shall be selected in a random manner from a list of full-time CSM employees. The Complainant and the Respondent shall each disqualify one of the initial panel members. The disqualifications to be exercised by the parties shall commence with the Complainant. Of the remaining initial panel members, the one chosen last shall serve as an alternate hearing panel member. The other three initial panel members shall constitute the hearing panel for the appeal. Prospective panel members may be excused on account of conflict of interest, health, or unavoidable absence from campus. An excused initial panel member shall be replaced by another initial panel member chosen in a random drawing prior to the exercise of disqualifications by either party.

E. Selection of Chief Panel Member

After a hearing panel has been chosen, the panel members shall elect a chief panel member from their number who shall preside throughout the remainder of the case.

1. Authority of Chief Panel Member

The chief panel member shall have the authority to (a) issue orders to compel discovery; (b) make rulings on evidentiary objections; and (c) issue any other orders necessary to control the conduct of the hearing and prohibit abusive treatment of witnesses, including removal of disruptive individuals from the hearing room.

2. Role of Alternate Hearing Panel Member

The alternate hearing panel member shall observe, but not actively participate in, all of the proceedings in the case and be prepared to substitute for a panel member who becomes unavailable during any stage of the case due to death, illness, or emergency.

F. Setting of Hearing Date

After a chief panel member has been chosen, a hearing date shall be set with reasonable consideration given to the schedules of the participants. The chief panel member shall set a date for the hearing, which shall occur no more than ninety days after the date upon which the formal complaint was filed with the Director of Human Resources. Once set, the hearing date may be rescheduled only with the concurrence of the Complainant, the Respondent, and the hearing panel.

G. Participation of Attorneys

Either party may engage the services of an attorney to assist in document preparation or case preparation. However, an attorney may not enter an appearance or formally participate in the case on behalf of either party.

H. Legal Advice for Hearing Panel

If the hearing panel desires legal advice at any time during the case, the chief panel member shall request such advice from the Office of Legal Services. An attorney from the Office of Legal Services shall provide the requested advice unless all such attorneys are actively involved in the case on behalf of one of the parties. In such event, the chief panel member shall request the desired legal advice from the Assistant Attorney General assigned to CSM, whose name and telephone number shall be provided to the chief panel member by the legal office.

I. Pre-Hearing Discovery

Informal discovery, or the exchange between the parties of information relevant to the case, is encouraged. If the parties cannot resolve such issues informally, either party may request the chief panel member up to ten days prior to the hearing date to enter an order compelling discovery upon a showing of the relevance of the requested information and the necessity of such information to case preparation. The other party may oppose such request by showing that the requested information is irrelevant, unnecessary to the requesting party's case preparation, or privileged according to law.

VII. Pre-Hearing Statements

A. Contents of Pre-Hearing Statements

Each party shall file a pre-hearing statement containing the following components:

1. Summary of the Argument: A concise statement summarizing the case from the position of the submitting party;
2. List of Issues: A list of the issues which the submitting party wishes the hearing panel to resolve;
3. List of Witnesses: A list of witnesses to be presented at the hearing along with a summary of the anticipated testimony of each witness; and
4. Photocopies of Exhibits: Photocopies of each exhibit to be presented at the hearing.

B. Deadlines for Pre-Hearing Statements

The Complainant shall file a pre-hearing statement with the hearing panel and provide a copy to the opposing party no later than ten days prior to the hearing date. The Respondent shall file a pre-hearing statement with the hearing panel and provide a copy to the opposing party no later than five days prior to the hearing date. If the hearing date is rescheduled, these time limits shall apply to the rescheduled hearing date.

C. Limitations Imposed by Pre-Hearing Statements

Neither party shall make an argument during the hearing which is inconsistent with the arguments set forth in the summary of the argument section of his or her pre-hearing statement. Neither party shall introduce any witnesses or exhibits at the hearing which are not listed in his or her pre-hearing statement. All exhibits listed in the pre-hearing statements

shall be deemed genuine and admissible unless successfully challenged prior to the hearing.

D. List of Hearing Issues

After examining the pre-hearing statements of both parties, the hearing panel shall prepare a list of issues to be resolved through the hearing and distribute such list to the parties no later than two days prior to the hearing date. The panel may list issues contained in the pre-hearing statement of either party or relevant issues not contained in the pre-hearing statement of either party. However, since the jurisdiction of the hearing panel is limited to hearing claims of unlawful discrimination, only issues directly related to the Complainant's claim of unlawful discrimination may be placed on the list of issues. The list of issues generated pursuant to this subparagraph shall be binding upon the subsequent hearing and shall form the standard against which all relevancy arguments shall be weighed.

E. Amendments to Pre-Hearing Statements

Up to two days prior to the hearing date, either party may request the chief panel member to permit amendments to his or her pre-hearing statement upon a showing of good cause and lack of prejudice to the opposing party. Any party filing an amended pre-hearing statement shall provide a copy thereof to the opposing party no later than the filing deadline imposed by the order granting leave to amend.

VIII. Hearing Procedures

A. Burden and Standard of Proof

The Complainant shall bear the burden of proof throughout the case. The standard of proof which the Complainant must meet to sustain the burden of proof shall be the preponderance of the evidence standard. The preponderance of the evidence standard shall be deemed met if the panel believes that it is more likely than not that the facts at issue occurred. The facts at issue shall include all facts which are required to be proven by the party bearing the burden of proof in order for such party to prevail.

B. Order of Presentation

Since the Complainant bears the burden of proof, that party shall present his or her case first. After the Complainant has finished, the Respondent shall present his or her case.

C. Outline of Hearing

The hearing shall proceed according to the following general outline:

1. Complainant's Opening Statement
2. Respondent's Opening Statement (unless reserved)
3. Complainant's Case
4. Respondent's Opening Statement (if reserved)
5. Respondent's Case
6. Complaint's Rebuttal Case (unless waived)

7. Respondent's Rebuttal Case (only if Complainant presents a rebuttal case and unless waived)
8. Complainant's Closing Argument
9. Respondent's Closing Argument
10. Complainant's Rebuttal Argument (unless waived)

D. Inapplicability of Strict Evidentiary Rules

Strict legal evidentiary rules shall not apply during the hearing. The chief panel member shall rule on the admissibility of disputed evidence with primary consideration given to the relevance, reliability, and probative value of proffered evidence.

E. Witness Examination Procedure

Each witness shall be directly examined by the party on whose behalf the witness has appeared to testify. Upon the conclusion of the direct examination of each witness, the opposing party shall be permitted the right of cross-examination. The chief panel member may permit re-direct and re-cross examination. However, an identical examination procedure shall be utilized for all witnesses testifying in a given hearing. Hearing panel members may interject questions at any time during the direct, cross, re-direct, or re-cross examinations.

IX. Post-Hearing Procedure

A. Recommendation of the Hearing Panel

Within a reasonable time after the conclusion of the hearing, the hearing panel shall confer among themselves and vote upon a recommended course of action. The panel members holding a majority point of view shall designate one of their number to write a recommendation reflecting their opinion. The panel members holding a minority point of view, if any, may issue a dissenting recommendation in a similar fashion.

B. Contents of Recommendation

The recommendation of the hearing panel shall include the following components:

1. Statement Regarding Burden of Proof: A statement regarding whether or not the hearing panel believes that the burden of proof borne by the Complainant has been sustained;
2. Findings of Fact: A list of the relevant facts found by the hearing panel upon which the recommendation is based;
3. Legal Conclusions: A list of the legal conclusions of the hearing panel upon which the determination of the issue of unlawful discrimination is based; and
4. Recommended Action: A statement regarding the relief for the Complainant, if any, that is being recommended by the hearing panel.

C. Issuance of Recommendation

The recommendation of the hearing panel shall be issued to the parties and delivered to the President along with the case file within fifteen days after the conclusion of the hearing.

D. Decision of President

The President shall examine the case file, consider the recommendation of the hearing panel, and issue a final written decision in the matter. The President shall possess the authority to affirm, reverse, or modify the recommendation of the hearing panel or to remand the matter to the panel for further proceedings or consideration. In the decision, the President may provide appropriate relief to the Complainant and may impose appropriate disciplinary action upon the Respondent. The decision of the President shall be delivered to the parties and the hearing panel within fifteen days from the date of the President's receipt of the recommendation and case file from the hearing panel, unless the President is unavailable for a significant amount of time during this period.

E. Presidential Unavailability

The term "unavailable," as utilized in this subsection and subsection X.D above, shall be defined to mean out of town, medically incapacitated, or engaged in important CSM business to the extent that sufficient time cannot be devoted to decision making hereunder. If the President is unavailable for a significant period of time during the decision making period, a letter shall be sent to the parties advising them of that fact as well as the anticipated date of presidential availability. In such event, the decision shall be due fifteen days from the date upon which the President becomes available. The President shall be the sole judge of presidential unavailability hereunder.

F. Appeal of Presidential Decision

There shall be no internal appeal from the final decision of the President. A party aggrieved by the decision of the President may file a complaint with the appropriate equal opportunity enforcement agency or pursue other available legal remedies.

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.

Colorado School Of Mines Sexual Harassment 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. (1988 Repl. Vol.) in order to set forth a policy concerning sexual harassment at CSM. This policy shall supersede any previously promulgated CSM policy which is in conflict herewith.

II. Sexual Harassment Policy

A. Definition of Sexual Harassment

Sexual harassment shall, without regard to the gender of the alleged perpetrator or victim, consist of unwelcome sexual advances, requests for sexual favors, and other verbal or physical conduct of a sexual nature when (1) submission to such conduct is made either explicitly or implicitly a term or condition of an individual's employment or scholastic endeavors; (2) submission to or rejection of such conduct by an individual is used as the basis for employment or academic decisions affecting the individual; or (3) such conduct has the purpose or effect of unreasonably interfering with an individual's work or school performance, or creating an intimidating, hostile, or offensive working or studying environment.

B. Policy Statement

CSM wishes to foster an environment for its students and employees which is free from all forms of sexual harassment, sexual intimidation, and sexual exploitation. Accordingly, CSM will not tolerate sexual harassment and will take all necessary measures to deter such misconduct and discipline violators of this policy with appropriate sanctions. Furthermore, 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. 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 sexual harassment.

C. Sanctions for Sexual Harassment

Appropriate sanctions may be imposed upon an employee or student who has sexually harassed another. The term Perpetrator shall be utilized herein to refer to such a person. The sanctions may include one or more of the following: verbal reprimand and warning, written reprimand and warning, student probation, suspension from registration, monetary fine, suspension without pay, expulsion, or termination. In determining appropriate sanctions for the offense, the decision maker shall consider the severity of the offense, aggravating and mitigating factors, and the Perpetrator's previous history of sexual harassment offenses. If the decision maker concludes that a lack of comprehension of the concept of sexual harassment is a factor in the offense, the Perpetrator can also be required to attend a sexual harassment seminar or workshop.

III. Persons Who May File a Complaint

A sexual harassment complaint may be filed by an individual described in one of the categories below:

A. Any person who believes that he or she has been sexually harassed by a member of the CSM community, including classified staff, exempt employees, and students;

B. Any person who believes that he or she has been threatened with or subjected to duress or retaliation by a member of the CSM community as a result of (1) opposing any perceived sexual harassment; (2) filing a complaint hereunder; (3) representing a Complainant hereunder; or (4) testifying, assisting, or participating in any manner in an investigation, proceeding, hearing, or lawsuit involving sexual harassment; or

C. The Human Resources Director or an attorney from the Office of Legal Services, if any of these individuals deem it to be in the best interest of CSM to do so.

IV. Informal Complaint Resolution Process

At the request of an individual who has come forward with a sexual harassment complaint, hereinafter the "Complainant," the Director of Human Resources shall assist in an attempt to resolve the complaint in an informal manner. Although verbal requests to proceed with the informal complaint resolution process will be honored, complainants are strongly encouraged to put such requests in writing. The informal sexual harassment complaint resolution process shall consist of an informal discussion between the Complainant and the individual accused of sexual harassment, hereinafter the "Respondent." The Director of Human Resources shall act as a mediator during this process, which shall be calculated to bring the complaint to the attention of the Respondent and elicit the voluntary cooperation of the Respondent in settling the matter. By attempting to resolve the sexual harassment complaint in an informal manner pursuant to the terms of this section, the Complainant shall not waive any rights to subsequently pursue the complaint through the formal sexual harassment complaint procedure set forth below.

V. Formal Complaint Procedure

A. Purpose

The purpose of the formal sexual harassment complaint procedure is to provide a formal mechanism for the prompt and fair internal resolution of complaints alleging sexual harassment. The procedure outlined below shall be the exclusive forum for the internal resolution of sexual harassment complaints at CSM.

B. Where to file a Complaint

All complaints by non-students alleging sexual harassment or retaliation shall be lodged with the Human Resources Office located on the second floor of Guggenheim Hall. Complaints by students alleging sexual harassment or retaliation may be submitted to the Human Resources Office, the Student Development Center, the Dean of Students, any faculty member, or any Resident Assistant. Any recipient of a student sexual harassment or retaliation complaint shall promptly forward such complaint to the Director of Human Resources for handling in accordance with the provisions set forth below.

C. Time Limits

A complaint may be lodged at any time, but CSM strongly encourages individuals who feel they have been victims of sexual harassment to come forward as soon as possible after the occurrence of the incident, event, or other action alleged to constitute sexual harassment or retaliation.

D. Contents of Complaint

Although a verbal sexual harassment complaint will be investigated, complainants are strongly encouraged to submit sexual harassment complaints in writing. Written complaints must be signed and must set forth specific factual matters believed to constitute sexual harassment or retaliation. The Complaint shall name as Respondent each individual whom the Complainant believes to have committed, participated in, or encouraged the sexual harassment or retaliation. The complaint shall also include a brief statement describing the relief requested by the Complainant.

E. Fulfillment of Complaint Prerequisites

As soon as practicable after receipt of the complaint, the Director of Human Resources shall submit the complaint to an attorney from the Office of Legal Services, who shall determine if the prerequisites outlined above have been fulfilled. If the prerequisites have not been fulfilled, the reviewing attorney shall inform the Complainant of the specifics of such determination in writing. The Complainant shall have the opportunity to correct any deficiencies and re-file the complaint. If the prerequisites have been fulfilled, the complaint will be handled as set forth below.

F. Choice of Remedies

No Complainant shall be permitted to simultaneously file an unlawful discrimination claim under the CSM Unlawful Discrimination Policy and Complaint Procedure and a sexual harassment claim under the CSM Sexual Harassment Policy and Complaint Procedure against the same individual arising out of an identical set of facts. In such a situation, a Complainant shall be entitled to file his or her claim under either, but not both, of the above-mentioned policies.

G. Notification of CSM Management Personnel

As soon as practicable after a determination has been made that the complaint is sufficient pursuant to subsection V.E above, the Office of Legal Services shall notify CSM Management Personnel of the complaint and provide them with a copy thereof. For the purpose this policy, the term CSM Management Personnel shall refer to the President, the vice president in whose area the Respondent is employed or enrolled, and, if applicable, the Respondent's immediate supervisor. However, if the President is the Respondent, the term CSM Management Personnel shall refer to the Board of Trustees, and if the Respondent is a vice president, the term "CSM Management Personnel" shall refer to the President.

H. Acknowledgment of Complaint and Notification of Respondent

As soon as practicable after being informed of the complaint pursuant to subsection V.G above, the vice president shall send a letter to the Complainant acknowledging receipt of the complaint. At the same time, the vice president shall notify the Respondent of the complaint in writing, and if the complaint has been reduced to writing, the vice president shall provide the Respondent with a copy thereof. If the President is the Respondent, the President of the Board of Trustees shall perform the above duties. If the Respondent is a vice president, the President shall perform these duties.

I. Investigation Authorization Form

Unless the complaint is initiated by an attorney from the Office of Legal Services or the Director of Human Resources pursuant to subsection III.C above, the Complainant shall be required to execute a Sexual Harassment Complaint Investigation Authorization Form prior to any investigation of the complaint.

J. Investigation of Complaint

An attorney from the Office of Legal Services and the Director of Human Resources shall jointly investigate the complaint by examining relevant documents, if any, and interviewing witnesses and other individuals designated by either party. The investigators will strive to conduct the investigation in a discrete and expeditious manner with due regard to thoroughness and fairness to both parties.

K. Confidentiality of Investigative Materials

All materials and documents prepared or compiled by the investigators during the course of investigating a sexual harassment complaint hereunder shall be kept confidential to the fullest extent of the law in order to protect interviewees and promote candor.

L. Alternate Investigators

If either an attorney from the Office of Legal Services or the Director of Human Resources is the Complainant or the Respondent hereunder, or is otherwise unavailable, the President shall appoint an alternate investigator.

M. Report of Findings and Confidential Recommendation

As soon as practicable after the conclusion of the investigation, the investigating attorney shall prepare and submit a report of findings and a confidential recommendation to CSM Management Personnel and the Director of Human Resources. The report of findings shall be provided to the Complainant and Respondent within a reasonable time following the issuance of a decision pursuant to subsection V.N below. The confidential recommendation shall not be released to the Complainant or the Respondent without written authorization from the President. The Director of Human Resources shall submit a separate recommendation to CSM Management Personnel which contains a statement of agreement or disagreement with the findings and recommendation of the investigating attorney.

N. Resolution of the Complaint

Following consultations with the President, the investigating attorney, and the Director of Human Resources, the vice president shall issue a final written decision regarding the complaint. The decision shall be addressed to the Complainant and shall contain a statement of whether or not sexual harassment was found to have occurred, the remedies to be provided to the Complainant, if any, and the sanctions to be imposed upon the Respondent, if any. At approximately the same time, the decision shall be communicated to the Respondent in writing. If sanctions are to be imposed upon the Respondent, the vice president shall also notify the Respondent of that aspect of the decision in writing. If the President is the Respondent, the President of the Board of Trustees shall perform the above duties. If the Respondent is a vice president, the President shall perform these duties.

O. Appeal of Final Decision

There shall be no internal appeal from the final decision rendered pursuant to subsection V.N above. A party aggrieved by the decision may file a complaint with the appropriate administrative agency or pursue other available legal remedies.

Promulgated by the CSM Board of Trustees on March 13, 1992. Amended by the CSM Board of Trustees on March 26, 1998. Amended by the CSM Board of Trustees on June 10, 1999. Amended by the CSM Board of Trustees on June 22, 2000.

Colorado School of Mines Personal Relationships Policy

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. (1988 Repl. Vol.) in order to set forth a policy concerning certain personal relationships at CSM as addressed herein. This policy shall supersede any previously promulgated CSM policy which is in conflict herewith.

II. Preface

Certain amorous, romantic, or sexual relationships in which the parties appear to have consented, but where a definite power differential exists between them, are of serious concern to CSM. Personal relationships which might be appropriate in other circumstances always pose inherent dangers when they occur between an Instructor and a Student, between a Person in a Position of Trust and a Student, and between a Supervisor and a Subordinate Employee. Although both parties to the relationship may have consented at the outset, such relationships are fundamentally asymmetric in nature. It is incumbent upon those with authority not to abuse, nor appear to abuse, the power with which they are entrusted. Accordingly, codes of ethics promulgated by most professional regulatory associations forbid professional-client amorous, romantic, or sexual relationships. The rela-

tionships prohibited by this policy shall be viewed in this context, and Instructors, Persons in Positions of Trust, and Supervisors should be aware that any violation of this policy shall result in formal disciplinary action against them.

III. Definitions

For the purposes of this policy, the following definitions shall apply:

A. Person in a Position of Trust: Any person occupying a position of trust with respect to one or more students at CSM such that engaging in an amorous, romantic, or sexual relationship with any student would compromise the ability of the employee to perform his or her duties. Examples of Persons in Positions of Trust at CSM are those employed in the Office of the Registrar, those employed in the Student Life Office, those employed in the Student Development Office, those employed in Public Safety, resident assistants, and paper graders. The above examples are provided for illustrative purposes only and are not intended to be exhaustive listings or to limit the illustrated category in any manner.

B. Instructor: Any person who teaches at CSM, including academic faculty members, instructional staff, and graduate students with teaching or tutorial responsibilities.

C. Student: Any person who is pursuing a course of study at CSM.

D. Subordinate Employee: Any person employed by CSM who is supervised by another employee.

E. Supervisor: Any person employed by CSM who occupies a position of authority over another employee with regard to hiring, administering discipline, conducting evaluations, granting salary adjustments, or overseeing task performance.

IV. Policy

A. Personal Relations Between Instructors and Students in the Instructional Context

No Instructor shall engage in an amorous, romantic, or sexual relationship, consensual or otherwise, with a Student who is enrolled in a course being taught by the Instructor, or whose academic work is being supervised by the Instructor.

B. Personal Relationships Between Instructors and Students Outside the Instructional Context

In a personal relationship between an Instructor and a Student for whom the Instructor has no current professional responsibility, the Instructor should be sensitive to the constant possibility that he or she may unexpectedly be placed in a position of responsibility for the instruction or evaluation of the Student. This could entail a request to write a letter of recommendation for the Student or to serve on an admissions or selection committee involving the Student. In addition, an awareness should be maintained that others may speculate that a specific power relationship exists even when none is

present, giving rise to assumptions of inequitable academic or professional advantage of the Student. Even if potential conflict of interest issues can be resolved, charges of sexual harassment may arise. In such situations, it is the Instructor who, by virtue of his or her special responsibility, shall be held accountable for unprofessional behavior.

C. Personal Relationships Between Supervisors and Subordinate Employees

No Supervisor shall engage in an amorous, romantic, or sexual relationship, consensual or otherwise, with a Subordinate Employee who reports, either directly or indirectly, to the Supervisor or is under the Supervisor's direct or indirect authority.

D. Personal Relationships Between Persons in Positions of Trust and Students

No Person in a Position of Trust shall engage in an amorous, romantic, or sexual relationship, consensual or otherwise, with a Student.

(Promulgated by the CSM Board of Trustees on February 14, 1992)

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