Mining Engineering

Degrees Offered

- Master of Science in Mining Engineering (Thesis or Non-Thesis)
- Doctor of Philosophy in Mining Engineering
- Master of Science in Earth Resource Development Engineering (Thesis or Non-Thesis)
- Doctor of Philosophy in Earth Resource Development Engineering

Program Description

The program has two distinctive, but inherently interwoven specialties.

The Mining Engineering area or specialty is predominantly for mining engineers and it is directed towards the traditional mining engineering fields. Graduate work is normally centered around subject areas such as mine planning and development, computer aided mine design, rock mechanics, operations research applied to the mineral industry, environment and sustainability considerations, mine mechanization, mine evaluation, finance and management and similar mining engineering topics.

The Earth Resources Development Engineering specialty is for those who wish to specialize in interdisciplinary fields that include understanding emerging technical and social issues in Earth Resources Development Engineering. This specialty is open to students with mining or non-mining engineering undergraduate degrees who are interested in scholarship and research on topics including, but not limited to, mining and sustainability, mine closure and reclamation engineering, corporate social responsibility, artisanal and small-scale mining, underground construction and tunneling engineering, mining and the environment, modeling and design in earth systems and processes, geothermal, explosive engineering, mine and construction management, mining related data science, earth observation for mine environmental monitoring and design and application of sensor networks, Internet of Things (IoT), robotics and Artificial Intelligence (AI) for autonomous mine systems.

Because of the interdisciplinary nature of this degree program, students will be required to take three core classes in the Mining Engineering Department and then choose courses related to their area of interest offered by mining, as well as other departments across campus.

Graduate work is normally centered around subject areas such as site characterization, environmental aspects, underground construction and tunneling (including microtunneling), excavation methods and equipment, mechanization of mines and underground construction, environmental and management aspects, modeling and design in geoengineering.

Mining Engineering

Program Description

Regarding academics and research the Mining Engineering Department focuses on fundamental areas including:

- Geomechanics, rock mechanics and stability of underground and surface excavations
- Computerized mine design and related applications (including geostatistical modeling)
- Advanced integrated mining systems incorporating mine mechanization and mechanical mining systems
- Underground excavation, tunneling and construction
- Construction and project management
- Site characterization and geotechnical investigations, modeling and design in geoengineering
- Rock fragmentation
- Mineral processing, comminution and separation technology
- Bulk material handling
- Mine ventilation
- Mine safety and health
- Corporate Social Responsibility and Sustainability
- Artisanal and Small-Scale Mining

Program Requirements

The Master of Science degree in Mining Engineering has two options available, Thesis and Non-Thesis.

For the PhD degree, students holding an MS degree in an appropriate field may transfer, with the approval of the Graduate Advisor and the Doctoral Committee, a maximum of 30 credit hours of graduate course work towards the credit hours to be completed for the PhD. The doctoral dissertation must be successfully defended before the approved Doctoral Committee.

Mining Engineering (MNEG) Degree Requirements

Master of Science - Thesis (MS-T). Students in the Mining Engineering MS-T degree program must take a minimum of 12 course credit hours of the 21 credit hour requirement from within the Mining Engineering Department. These must include the core requirement courses listed below, unless waived by the Master's Thesis Committee.

Course work credits (minimum) 21.0
Research credits (maximum) 9.0
Total credits (minimum) 30.0

Master of Science - Non-thesis (MS-NT). Students in the Mining Engineering MS-NT program must take a minimum of 21 credit hours of course work from within Mining Engineering Department. These must include the core requirement courses listed below unless waived. A maximum of 9 semester hours of 400 level courses can be applied to the credit hours required.

Total course work credits (minimum) 30.0

Mines’ Combined Undergraduate / Graduate Degree Program

Students enrolled in Mines’ combined undergraduate/graduate program (meaning uninterrupted registration from the time the student earns a Mines undergraduate degree to the time the student begins a Mines graduate degree) may double count up to six hours of credits which were used in fulfilling the requirements of their undergraduate degree at Mines, towards their graduate program. Any 400+ level courses that count towards the undergraduate degree requirements as “Elective Coursework” or any 500+ level course, may be used for the purposes of double counting at the discretion of the graduate advisor. These courses must have been passed with a “B-” or better, not be substitutes for
required coursework, and meet all other University, Department, Division, and Program requirements for graduate credit.

Doctor of Philosophy

Maximum of 48 semester credit hours of course work is required. A maximum of 30 units can be transferred from a MS degree program. The student's Graduate Committee must approve the transfer of these units. A minimum of 18 credit course hours must be taken in the Mining Engineering Department. A maximum of 9 semester hours of 400 level courses can be applied to the credit hours required.

Course work credits (minimum) 48.0
Research credits (minimum) 24.0
Credit hours beyond the BS degree (required) 72.0

Other PhD Requirements

• A minimum of 18 hours of course work must be completed at the Colorado School of Mines. A minimum of 9 credits beyond the Master's degree must be completed in the Mining Engineering Department. Exceptions may be approved by the PhD Dissertation Committee.

• Those with an MS in an appropriate field may transfer a maximum of 30 credit hours of course work towards the course work requirement, subject to the approval by the Advisor and Doctoral Committee.

• The doctoral dissertation thesis must be successfully defended before the Doctoral Committee.

• Assessment Exam, usually taken at the end of the first year in the PhD program.

• Minimum GPA requirement: 3.0/4.0.

• Thesis Proposal Approval.

• Comprehensive Exams, oral mandatory, written may be waived at the discretion of the Doctoral Committee.

Required Core Courses for either the MS or PhD degree:

Two of the following three graduate courses are required to be completed to receive a Mining Engineering graduate degree at Mines:

MNGN508 ADVANCED ROCK MECHANICS 3.0
MNGN512 SURFACE MINE DESIGN 3.0
MNGN516 UNDERGROUND MINE DESIGN 3.0

Prerequisites

Students entering the Mining Engineering graduate program for either the master's or doctoral degree are expected to have completed an undergraduate ABET-accredited BS degree in Mining Engineering. Deficiencies, if any, will be determined by the Department of Mining Engineering on the basis of a student's academic record and experience. For specific information on prerequisites, students are encouraged to refer to the Mining Engineering Department's Graduate Handbook, available from the Department of Mining Engineering or on the web site at https://mining.mines.edu/graduate-program/.

Earth Resources Development Engineering

Program Description

The Earth Resources Development Engineering specialty is for those who wish to specialize in interdisciplinary fields that include understanding emerging technical and social issues in Earth Resources Development Engineering. This specialty is open to students with mining or non-mining engineering undergraduate degrees who are interested in scholarship and research on topics including, but not limited to, mining and sustainability, mine closure and reclamation engineering, corporate social responsibility, artisanal and small-scale mining, underground construction and tunneling engineering, mining and the environment, modeling and design in earth systems and processes, geothermal, explosive engineering, mine and construction management, mining related data science, earth observation for mine environmental monitoring and design and application of sensor networks, Internet of Things (IoT), robotics and Artificial Intelligence (AI) for autonomous mine systems. Because of the interdisciplinary nature of this degree program, students will be required to take three core classes in the Mining Engineering Department and then choose courses related to their area of interest offered by mining, as well as other departments across campus.

The Master of Science in Earth Resources Development Engineering has two MS degree options (thesis and non-thesis). For the PhD degree, students holding an MS degree in a relevant field may transfer, with the approval of the doctoral committee, a maximum of 30 credit hours of graduate course work towards the required credit hours for the PhD degree. The doctoral dissertation must be successfully defended before the approved doctoral committee.

Earth Resource Development Engineering (ERDE) Degree Requirements

Master of Science - Thesis (MS-T). Students in the ERDE MS-T program must take a minimum of 15 credit hours from within the Mining Engineering Department. These must include the required core courses listed below unless waived by the Master's Thesis Committee.

Course work credits (minimum) 21.0
Research credits (maximum) 9.0
Total credits (minimum) 30.0

Master of Science - Non-Thesis (MS-NT). Students in the ERDE MS-NT program must take a minimum of 15 credit hours of course work from within Mining Engineering Department. These must include the required core courses listed below unless waived. A maximum of 9 semester hours of 400 level courses can be applied to the course credit hours required.

Total course work credits (minimum) 30.0

Mines’ Combined Undergraduate / Graduate Degree Program

Students enrolled in Mines’ combined undergraduate/graduate program (meaning uninterrupted registration from the time the student earns a Mines undergraduate degree to the time the student begins a Mines graduate degree) may double count up to six hours of credits which were used in fulfilling the requirements of their undergraduate degree at Mines, towards their graduate program. Any 400+ level courses that count towards the undergraduate degree requirements as "Elective Coursework" or any 500+ level course, may be used for the purposes of
double counting at the discretion of the graduate advisor. These courses must have been passed with a "B-" or better, not be substitutes for required coursework, and meet all other University, Department, Division, and Program requirements for graduate credit.

**Doctor of Philosophy**

Maximum of 48 semester credit hours of course work, where a maximum of 30 units can be transferred from a M.S. degree program. The student's Graduate committee must approve the transfer of these units. A minimum of 9 credit course hours must be taken in the Mining Engineering Department. These must include the required core courses listed below unless waived. A maximum of 9 semester hours of 400 level courses can be applied to the credit hours required.

| Course work credits (minimum) | 48.0 |
| Research credits (minimum)    | 24.0 |
| Credit hours beyond the BS degree (required) | 72.0 |

**Other PhD Requirements**

- A minimum of 18 hours of course work must be completed at the Colorado School of Mines. A minimum of 9 credits beyond the Master's degree must be completed in the Mining Engineering Department. Exceptions may be approved by the PhD Dissertation Committee.
- Those with an MS in an appropriate field may transfer a maximum of 30 credit hours of course work towards the course work requirement, subject to the approval by the Advisor and doctoral committee.
- The doctoral dissertation thesis must be successfully defended before the doctoral committee.
- Assessment Exam, usually taken at the end of the first year in the PhD program.
- Minimum GPA requirement: 3.0/4.0.
- Thesis Proposal Approval.
- Comprehensive Exams, oral mandatory, written may be waived at the discretion of the Doctoral Committee.

**Required Core Courses for either the MS or PhD degree:**

*The following course is required:*

MNGN510  **FUNDAMENTALS OF MINING AND MINERAL RESOURCE DEVELOPMENT**  3.0

*In addition, two of the following four courses are required:*

MNGN5XX  Sustainable Development and Earth Resources  3.0
MNGN556  MINE WATER AND ENVIRONMENT  3.0
MNGN5XX  Big Data Analytics for Earth Resources Sciences and Engineering  3.0
MNGN528  MINING GEOLOGY  3.0

**Prerequisites**

Students entering the ERDE graduate program for either the master's or doctoral degree are expected to have completed the equivalent of an undergraduate ABET-accredited BS degree in some discipline of engineering. Deficiencies, if any, will be determined by the Department of Mining Engineering on the basis of a student's academic record and experience. For specific information on prerequisites, students are encouraged to refer to the Mining Engineering Department's Graduate Handbook, available from the Department of Mining Engineering or on the web site at https://mining.mines.edu/graduate-program/.

**Department Head**

Priscilla P. Nelson

**Associate Department Head**

Jürgen Brune

**Professors**

Corby Anderson
Kadri Dagdelen
H. Sebnem Düzgün
Linda Figueroa
Priscilla P. Nelson
M. Ugur Ozbay
Patrick R. Taylor

**Associate Professors**

Mark Kuchta
Hugh B. Miller
Masami Nakagawa
Jamal Rostami

**Assistant Professors**

Elizabeth A. Holley
Rennie Kaunda
Eunhye Kim
Nicole Smith

**Professors of Practice**

Jürgen Brune
Barbara Filas
John Grubb
Robert Reeves

**Research Professor**

D. Erik Spiller

**Research Associate Professor**

Vilem Petr

**Research Assistant Professor**

Richard Gilmore
Adjunct Faculty
Matt Collins
Matt Morris
Andy Schissler
William R. Wilson

Courses
GOGN501. SITE INVESTIGATION AND CHARACTERIZATION. 3.0 Semester Hrs.
An applications oriented course covering: geological data collection, geophysical methods for site investigation; hydrological data collection; materials properties determination; and various engineering classification systems. Presentation of data in a format suitable for subsequent engineering design will be emphasized. Prerequisite: Introductory courses in geology, rock mechanics, and soil mechanics. 3 hours lecture; 3 semester hours.

GOGN502. SOLID MECHANICS APPLIED TO ROCKS. 3.0 Semester Hrs.
An introduction to the deformation and failure of rocks and rock masses and to the flow of groundwater. Principles of displacement, strain and stress, together with the equations of equilibrium are discussed. Elastic and plastic constitutive laws, with and without time dependence, are introduced. Concepts of strain hardening and softening are summarized. Energy principles, energy changes caused by underground excavations, stable and unstable equilibria are defined. Failure criteria for intact rock and rock masses are explained. Principles of numerical techniques are discussed and illustrated. Basic laws and modeling of groundwater flows are introduced. Prerequisite: Introductory Rock Mechanics. 3 hours lecture; 3 semester hours.

GOGN503. CHARACTERIZATION AND MODELING LABORATORY. 3.0 Semester Hrs.
An applications oriented course covering: Advanced rock testing procedures; dynamic rock properties determination; on-site measurements; and various rock mass modeling approaches. Presentation of data in a format suitable for subsequent engineering design will be emphasized. Prerequisite: Introductory courses in geology, rock mechanics, and soil mechanics. 3 hours lecture; 3 semester hours.

GOGN504. SURFACE STRUCTURES IN EARTH MATERIALS. 3.0 Semester Hrs.

GOGN505. UNDERGROUND EXCAVATION IN ROCK. 3.0 Semester Hrs.
Components of stress, stress distributions, underground excavation failure mechanisms, optimum orientation and shape of excavations, excavation stability, excavation support design, ground treatment and rock pre-reinforcement, drill and blast excavations, mechanical excavation, material haulage, ventilation and power supply, labor requirements and training, scheduling and costing of underground excavations, and case histories. Prerequisites: GOGN501, GOGN502, GOGN503. 3 hours lecture; 3 semester hours.

GOGN625. GEO-ENGINEERING SEMINAR. 1.0 Semester Hr.
Discussions presented by graduate students, staff, and visiting lecturers on research and development topics of general interest. Required of all graduate students in Geo-Engineering every semester, during residence. Prerequisite: Enrollment in Geo-Engineering Program. 1 semester hour upon completion of thesis or residence.

MNGN501. REGULATORY MINING LAWS AND CONTRACTS. 3.0 Semester Hrs.
(I) Basic fundamentals of engineering law, regulations of federal and state laws pertaining to the mineral industry and environment control. Basic concepts of mining contracts. Offered in even numbered years. Prerequisite: Senior or graduate status. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN503. MINING TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT. 3.0 Semester Hrs.
(I, II) The primary focus of this course is to provide students an understanding of the fundamental principles of sustainability and how they influence the technical components of a mine's life cycle, beginning during project feasibility and extending through operations to closure and site reclamation. Course discussions will address a wide range of traditional engineering topics that have specific relevance and impact to local and regional communities, such as mining methods and systems, mine plant design and layout, mine operations and supervision, resource utilization and cutoff grades, and labor. The course will emphasize the importance of integrating social, political, and economic considerations into technical decision-making and problem solving. 3 hours lecture; 3 semester hours.

MNGN504. UNDERGROUND CONSTRUCTION ENGINEERING IN HARD ROCK. 3.0 Semester Hrs.
(I) This course is developed to introduce students to the integrated science, engineering, design and management concepts of engineered underground construction. The course will cover advanced rock engineering in application to underground construction, geological interpretation and subsurface investigations, equipment options and system selection for projects with realistic constraints, underground excavation initial support and final shotcrete/lining design, and approaches to uncertainty evaluation and risk assessment for underground construction projects. Team design projects and presentations will be required. Prerequisites: CEEN513. Co-requisites: GEGN562. 3 hours lecture; 3 semester hours.

MNGN505. ROCK MECHANICS IN MINING. 3.0 Semester Hrs.
(I) The course deals with the rock mechanics aspect of design of mine layouts developed in both underground and surface. Underground mining sections include design of coal and hard rock pillars, mine layout design for tabular and massive ore bodies, assessment of caving characteristics or ore bodies, performance and application of backfill, and phenomenon of rock burst and its alleviation. Surface mining portion covers rock mass characterization, failure modes of slopes excavated in rock masses, probabilistic and deterministic approaches to design of slopes, and remedial measures for slope stability problems. Prerequisite: MN321 or equivalent. 3 hours lecture; 3 semester hours.
MNGN506. DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS. 3.0 Semester Hrs.
Design of underground excavations and support. Analysis of stress and rock mass deformations around excavations using analytical and numerical methods. Collections, preparation, and evaluation of insitu and laboratory data for excavation design. Use of rock mass rating systems for site characterization and excavation design. Study of support types and selection of support for underground excavations. Use of numerical models for design of shafts, tunnels and large chambers. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN507. ADVANCED DRILLING AND BLASTING. 3.0 Semester Hrs.
(I) An advanced study of the theories of rock penetration including percussion, rotary, and rotary percussion drilling. Rock fragmentation including explosives and the theories of blasting rock. Application of theory to drilling and blasting practice at mines, pits, and quarries. Prerequisite: MNGN407. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN508. ADVANCED ROCK MECHANICS. 3.0 Semester Hrs.
Equivalent with MNGN418, (I, II, S) Analytical and numerical modeling analysis of stresses and displacements induced around engineering excavations in rock. Insitu stress. Rock failure criteria. Complete load deformation behavior of rocks. Measurement and monitoring techniques in rock mechanics. Principles of design of excavation in rocks. Analytical, numerical modeling and empirical design methods. Probabilistic and deterministic approaches to rock engineering designs. Excavation design examples for shafts, tunnels, large chambers and mine pillars. Seismic loading of structures in rock. Phenomenon of rock burst and its alleviation. One additional design project will be assigned to graduate students. Prerequisites: MNGN321. 3 hours lecture; 3 semester hours.

MNGN509. CONSTRUCTION ENGINEERING AND MANAGEMENT. 3.0 Semester Hrs.
Equivalent with GEGN562, (II) The course will provide content, methods and experience in construction planning and cost estimating, scheduling and equipment performance, contractual delivery systems and relationships, key contract clauses, risk registration and management, and project controls. Special attention will be paid to geotechnical uncertainty and risk, emerging technologies and industry trends, and to ethics and sustainability as applied to construction engineering and management practices. Co-requirements: GEGN562. 3 hours lecture; 3 semester hours.

MNGN510. FUNDAMENTALS OF MINING AND MINERAL RESOURCE DEVELOPMENT. 3.0 Semester Hrs.
Specifically designed for non-majors, the primary focus of this course is to provide students with a fundamental understanding of how mineral resources are found, developed, mined, and ultimately reclaimed. The course will present a wide range of traditional engineering and economic topics related to: exploration and resource characterization, project feasibility, mining methods and systems, mine plant design and layout, mine operations and scheduling, labor, and environmental and safety considerations. The course will emphasize the importance of integrating social (human), political, and environmental issues into technical decision-making and design. 3 hours lecture; 3 semester hours.

MNGN511. MINING INVESTIGATIONS. 2-4 Semester Hr.
(I, II) Investigational problems associated with any important aspect of mining. Choice of problem is arranged between student and instructor. Prerequisite: none. Lecture, consultation, lab, and assigned reading; 2 to 4 semester hours.

MNGN512. SURFACE MINE DESIGN. 3.0 Semester Hrs.
Analysis of elements of surface mine operation and design of surface mining system components with emphasis on minimization of adverse environmental impact and maximization of efficient use of mineral resources. Ore estimates, unit operations, equipment selection, final pit determinations, short- and long-range planning, road layouts, dump planning, and cost estimation. Prerequisite: MNGN210. 3 hours lecture; 3 semester hours.

MNGN514. MINING ROBOTICS. 3.0 Semester Hrs.
(I) Fundamentals of robotics as applied to the mining industry. The focus is on mobile robotic vehicles. Topics covered are mining applications, introduction and history of mobile robotics, sensors, including vision, problems of sensing variations in rock properties, problems of representing human knowledge in control systems, machine condition diagnostics, kinematics, and path finding. Prerequisite: CSCI404. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN515. MINE MECHANIZATION AND AUTOMATION. 3.0 Semester Hrs.
This course will provide an in-depth study of the current state of the art and future trends in mine mechanization and mine automation systems for both surface and underground mining, review the infrastructure required to support mine automation, and analyze the potential economic and health and safety benefits. Prerequisite: MNGN312, MNGN314, MNGN316. 2 hours lecture, 3 hours lab; 3 semester hours. Fall of odd years.

MNGN516. UNDERGROUND MINE DESIGN. 3.0 Semester Hrs.
Selection, design, and development of most suitable underground mining methods based upon the physical and the geological properties of mineral deposits (metallics and nonmetallics), conservation considerations, and associated environmental impacts. Reserve estimates, development and production planning, engineering drawings for development and extraction, underground haulage systems, and cost estimates. Prerequisite: MNGN210. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN517. ADVANCED UNDERGROUND MINING. 3.0 Semester Hrs.
(II) Review and evaluation of new developments in advanced underground mining systems to achieve improved productivity and reduced costs. The major topics covered include: mechanical excavation techniques for mine development and production, new haulage and vertical conveyance systems, advanced ground support and roof control methods, mine automation and monitoring, new mining systems and future trends in automated, high productivity mining schemes. Prerequisite: Underground Mine Design (e.g., MNGN314). 3 hours lecture; 3 semester hours.

MNGN518. ADVANCED BULK UNDERGROUND MINING TECHNIQUES. 3.0 Semester Hrs.
This course will provide advanced knowledge and understanding of the current state-of-the-art in design, development, and production in underground hard rock mining using bulk-mining methods. Design and layout of sublevel caving, block caving, open stoping and blasthole stoping systems. Equipment selection, production scheduling, ventilation design, and mining costs. Prerequisites: MNGN314, MNGN516. 2 hours lecture, 3 hours lab; 3 semester hours. Spring of odd years.
MNGN519. ADVANCED SURFACE COAL MINE DESIGN. 3.0 Semester Hrs.
(I) Review of current manual and computer methods of reserve estimation, mine design, equipment selection, and mine planning and scheduling. Course includes design of a surface coal mine for a given case study and comparison of manual and computer results. Prerequisite: MNGN312, 316, 427. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in odd years.

MNGN520. ROCK MECHANICS IN UNDERGROUND COAL MINING. 3.0 Semester Hrs.
(I) Rock mechanics consideration in the design of room-and-pillar, longwall, and shortwall coal mining systems. Evaluation of bump and outburst conditions and remedial measures. Methane drainage systems. Surface subsidence evaluation. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN522. FLOTATION. 3.0 Semester Hrs.
Science and engineering governing the practice of mineral concentration by flotation. Interfacial phenomena, flotation reagents, mineral-reagent interactions, and zeta-potential are covered. Flotation circuit design and evaluation as well as tailings handling are also covered. The course also includes laboratory demonstrations of some fundamental concepts. 3 hours lecture; 3 semester hours.

MNGN523. SELECTED TOPICS. 2-4 Semester Hr.
(I, II) Special topics in mining engineering, incorporating lectures, laboratory work or independent study, depending on needs. This course may be repeated for additional credit only if subject material is different. Prerequisite: none. 2 to 4 semester hours. Repeatable for credit under different titles.

MNGN524. ADVANCED MINE VENTILATION. 3.0 Semester Hrs.
(I) Advanced topics of mine ventilation including specific ventilation designs for various mining methods, ventilation numerical modeling, mine atmosphere management, mine air cooling, prevention and ventilation response to mine fires and explosions, mine dust control. Prerequisites: MNGN424 Mine Ventilation. Lecture and Lab Contact Hours: 3 hours lecture; 3 semester credit hours.

MNGN525. INTRODUCTION TO NUMERICAL TECHNIQUES IN ROCK MECHANICS. 3.0 Semester Hrs.
(I) Principles of stress and infinitesimal strain analysis are summarized, linear constitutive laws and energy methods are reviewed. Continuous and laminated models of stratified rock masses are introduced. The general concepts of the boundary element and finite element methods are discussed. Emphasis is placed on the boundary element approach with displacement discontinuities, because of its relevance to the modeling of the extraction of tabular mineral bodies and to the mobilization of faults, joints, etc. Several practical problems, selected from rock mechanics and subsidence engineering practices, are treated to demonstrate applications of the techniques. Prerequisite: MNGN321, EGGE320, or equivalent courses, MATH455. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN526. MODELING AND MEASURING IN GEOMECHANICS. 3.0 Semester Hrs.
(II) Introduction to instruments and instrumentation systems used for making field measurements (stress, convergence, deformation, load, etc.) in geomechanics. Techniques for determining rock mass strength and deformability. Design of field measurement programs. Interpretation of field data. Development of predictive models using field data. Introduction to various numerical techniques (boundary element, finite element, FLAC, etc.) for modeling the behavior of rock structures. Demonstration of concepts using various case studies. Prerequisite: Graduate standing. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in odd years.

MNGN527. THEORY OF PLATES AND SHELLS. 3.0 Semester Hrs.
Classical methods for the analysis of stresses in plate type structures are presented first. The stiffness matrices for plate element will be developed and used in the finite element method of analysis. Membrane and bending stresses in shells are derived. Application of the theory to tunnels, pipes, pressures vessels, and domes, etc., will be included. Prerequisites: EGGN320. 3 hours lecture; 3 credit hours.

MNGN528. MINING GEOLOGY. 3.0 Semester Hrs.
(I) Role of geology and the geologist in the development and production stages of a mining operation. Topics addressed: mining operation sequence, mine mapping, drilling, sampling, reserve estimation, economic evaluation, permitting, support functions. Field trips, mine mapping, data evaluation, exercises and term project. Prerequisite: GEGN401 or GEGN405. 2 hours lecture/seminar, 3 hours laboratory: 3 semester hours. Offered in even years.

MNGN529. URANIUM MINING. 2.0 Semester Hrs.
(I) Overview and introduction to the principles of uranium resource extraction and production. All aspects of the uranium fuel cycle are covered, including the geology of uranium, exploration for uranium deposits, mining, processing, environmental issues, and health and safety aspects. A lesser emphasis will be placed on nuclear fuel fabrication, nuclear power and waste disposal.

MNGN530. INTRODUCTION TO MICRO COMPUTERS IN MINING. 3.0 Semester Hrs.
(I) General overview of the use of PC based micro computers and software applications in the mining industry. Topics include the use of: database, CAD, spreadsheets, computer graphics, data acquisition, and remote communications as applied in the mining industry. Prerequisite: Any course in computer programming. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN536. OPERATIONS RESEARCH TECHNIQUES IN THE MINERAL INDUSTRY. 3.0 Semester Hrs.
Analysis of exploration, mining, and metallurgy systems using statistical analysis. Monte Carlo methods, simulation, linear programming, and computer methods. Prerequisite: MNGN433. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in even years.

MNGN538. GEOSTATISTICAL ORE RESERVE ESTIMATION. 3.0 Semester Hrs.
(I) Introduction to the application and theory of geostatistics in the mining industry. Review of elementary statistics and traditional ore reserve calculation techniques. Presentation of fundamental geostatistical concepts, including: variogram, estimation variance, block variance, kriging, geostatistical simulation. Emphasis on the practical aspects of geostatistical modeling in mining. Prerequisite: MATH323 or equivalent course in statistics; graduate or senior status. 3 hours lecture; 3 semester hours.
MNGN539. ADVANCED MINING GEOSTATISTICS. 3.0 Semester Hrs.
(II) Advanced study of the theory and application of geostatistics in mining engineering. Presentation of state-of-the-art geostatistical concepts, including: robust estimation, nonlinear geostatistics, disjunctive kriging, geostatistical simulation, computational aspects. This course includes presentations by many guest lecturers from the mining industry. Emphasis on the development and application of advanced geostatistical techniques to difficult problems in the mining industry today. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN540. CLEAN COAL TECHNOLOGY. 3.0 Semester Hrs.
(I, II) Clean Energy - Gasification of Carbonaceous Materials - including coal, oil, gas, plastics, rubber, municipal waste and other substances. This course also covers the process of feedstock preparation, gasification, cleaning systems, and the output energy blocks along with an educational segment on CO products. These output energy blocks include feedstock to electrical power, feedstock to petroleum liquids, feedstock to pipeline quality gas. The course covers co-product development including urea, fertilizers, CO2 extraction/sequestration and chemical manufacturing.

MNGN545. ROCK SLOPE ENGINEERING. 3.0 Semester Hrs.
Introduction to the analysis and design of slopes excavated in rock. Rock mass classification and strength determinations, geological structural parameters, properties of fracture sets, data collection techniques, hydrological factors, methods of analysis of slope stability, wedge intersections, monitoring and maintenance of final pit slopes, classification of slides. Deterministic and probabilistic approaches in slope design. Remedial measures. Laboratory and field exercise in slope design. Collection of data and specimens in the field for deterring physical properties required for slope design. Application of numerical modeling and analytical techniques to slope stability determinations for hard rock and soft rock environments. Prerequisite: none. 3 hours lecture. 3 semester hours.

MNGN546. PM - MINE HEALTH AND SAFETY. 2.0 Semester Hrs.
(I, II, S) This course describes the principles of providing a safe and healthy work environment, focusing on the cultural and behavioral elements. Realigning long-learned human behaviors into a culture of safety and health consciousness is a significant management challenge, particularly in the developing world. Learning emphasis will be balanced among fundamentals, future trends, but risk will be a driver among discussion topics. Health and safety will be discussed in the context of the project cycle and also how the culture can transcend the workplace through mine employees to their families, neighbors and communities. 2 hours lecture; 2 semester hours.

MNGN547. PM - GEOLOGY AND MINING. 3.0 Semester Hrs.
(I, II, S) This course presents the relationship between geology and mining including the genesis of ore deposits, exploration, geochemistry, resource assessment, and mine planning. The relationship between the risks associated with reserve estimates and project finance are discussed. 3 hours lecture; 3 semester hours.

MNGN548. PM - INTEGRATED INFORMATION AND MINE SYSTEMS MANAGEMENT. 3.0 Semester Hrs.
(I, II, S) This course presents facilities external to the mine that are necessary to support and maintain mining and waste handling operations, gather, store, and evaluate operating and maintenance databases. Focus will be on systems integration, emerging trends, automation, internet of things (IoT), managing big data systems, cyber security, sensors, and data evaluation. 3 hours lecture; 3 semester hours.

MNGN549. MARINE MINING SYSTEMS. 3.0 Semester Hrs.
(I) Define interdisciplinary marine mining systems and operational requirements for the exploration survey, sea floor mining, hoisting, and transport. Describe and design components of deep-ocean, manganese-nodule mining systems and other marine mineral extraction methods. Analyze dynamics and remote control of the marine mining systems interactions and system components. Describe the current state-of-the-art technology, operational practice, trade-offs of the system design and risk. Prerequisite: EGGN351, EGGN320, GEOC408. 3 hours lecture; 3 semester hours. Offered alternate even years.

MNGN550. NEW TECHNIQUES IN MINING. 3.0 Semester Hrs.
(II) Review of various experimental mining procedures, including a critical evaluation of their potential applications. Mining methods covered include deep sea nodule mining, in situ gasification of coal, in situ retorting of oil shale, solution mining of soluble minerals, in situ leaching of metals, geothermal power generation, oil mining, nuclear fragmentation, slope caving, electro-thermal rock penetration and fragmentation. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN551. PM - MINE ACCOUNTING. 2.0 Semester Hrs.
(I, II, S) This course presents basic principles of accounting for mine engineers and managers. The preparation, content and analysis of financial statements and balance sheets from a managerial perspective are presented. Cost and accrual accounting for mine projects and operations is covered. Accounting standards in the U.S. and internationally are discussed. Mandatory financial reporting requirements for corporate entities are included in the course. 2 hours lecture; 2 semester hours.

MNGN552. SOLUTION MINING AND PROCESSING OF ORES. 3.0 Semester Hrs.
(II) Theory and application of advanced methods of extracting and processing of minerals, underground or in situ, to recover solutions and concentrates of value-materials, by minimization of the traditional surface processing and disposal of tailings to minimize environmental impacts. Prerequisite: Senior or graduate status. 3 hours lecture, 3 semester hours. Offered in spring.

MNGN553. PM - MINE DESIGN AND OPERATION PLANNING. 3.0 Semester Hrs.
(I, II, S) This course provides an overview of mine design and operating fundamentals with a focus on the emerging trends that will influence the mining industry. Topics provide an overarching significance to social, environmental, and sustainable factors during the design and operation of underground and surface mine planning. 3 hours lecture; 3 semester hours.

MNGN554. PM - MINE FINANCE. 2.0 Semester Hrs.
(I, II, S) This course applies the basic principles and concepts of financing in the mining industry. All methods of accessing capital for U.S. and international mining projects and operations will be presented. Asset and cash management throughout the mine life cycle will be discussed. Approaches to mergers and acquisitions, dividend policy and other financial decisions will be examined. Financial ratios, auditing and other financial controls will be taught. 2 hours lecture; 2 semester hours.
MNGN555. PM - MINE INVESTMENT EVALUATION. 3.0 Semester Hrs.
(I, II, S) This course provides an education in the evaluation of mine capital investments applying the principles of time value of money to after-tax cash flows. Implications of taxes, sustainability funding and debt financing are included. Methods of cost estimation for capital and operating budgets for feasibility studies are taught. The required content of feasibility studies at varying levels of detail is discussed. World standards for resource and reserve determination and public reporting requirements are presented. Methods for sensitivity analysis and real options analysis of mine capital investments are demonstrated. 3 hours lecture; 3 semester hours.

MNGN556. MINE WATER AND ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with CEEN556.
(I) This course will cover core aspects of mine water and mining geotechnics. The main topics to be covered relate to surface and groundwater flow along open pits and underground excavations, tailings and impoundments, mine spoils and waste rock, reclamation and closure. Course emphasizes leadership, teamwork, communication, and creative problem solving skills through the use of case examples, homework, and exams which emphasize typical water and geotechnical problems relevant to the mining industry. Prerequisite: CHGN121, CHGN122. 3 hours lecture, 3 semester hours.

MNGN557. PM - MINERAL ECONOMICS AND POLICY. 2.0 Semester Hrs.
(I, II, S) This course explores the determinants of demand for minerals and the factors that change that demand. The course covers sources of supply - primary, secondary and recycling for mineral commodities. The interaction of supply and demand and the impact on mineral markets is discussed. Public policy as it applies to taxation, economic development and sustainability is presented in both historical and future perspectives. 2 hours lecture; 2 semester hours.

MNGN558. PM - MINERAL PROCESSING. 3.0 Semester Hrs.
(I, II, S) This course presents the fundamentals for devising and specifying mineral processing systems to handle and beneficcate ores into salable concentrates. Ore sampling, testing programs, evaluations, and presentation methods are discussed. Emphasis is made to water and energy requirements, tailings management, and mill development from concept, construction, and operations. 3 hours lecture; 3 semester hours.

MNGN559. MECHANICS OF PARTICULATE MEDIA. 3.0 Semester Hrs.
(1) This course allows students to establish fundamental knowledge of quasi-static and dynamic particle behavior that is beneficial to interdisciplinary material handling processes in the chemical, civil, materials, metallurgy, geophysics, physics, and mining engineering. Issues of interest are the definition of particl size and size distribution, particle shape, nature of packing, quasi-static behavior under different external loading, particle collisions, kinetic theoretical modeling of particulate flows, molecular dynamic simulations, and a brief introduction of solid-fluid two-phase flows. Prerequisite: none. 3 hours lecture; 3 semester hours. Fall semesters, every other year.

MNGN560. INDUSTRIAL MINERALS PRODUCTION. 3.0 Semester Hrs.
(II) This course describes the engineering principles and practices associated with quarry mining operations related to the cement and aggregate industries. The course will cover resource definition, quarry planning and design, extraction, and processing of minerals for cement and aggregate production. Permitting issues and reclamation, particle sizing and environmental practices, will be studied in depth.

MNGN561. PM - PROJECT MANAGEMENT. 3.0 Semester Hrs.
(I, II, S) This course covers project management from major mine construction projects to business improvement projects. Project organization, delivery methods, controls and other aspects of managing projects big and small will be included. Methods for creating improvement results, managing risk, decision-making under conditions of uncertainty and optimizing mining processes will be discussed extensively. Strategies for resolving conflicts that occur in business will be taught. 3 hours lecture; 3 semester hours.

MNGN562. PM - MINING ENVIRONMENTAL AND SOCIAL RESPONSIBILITY. 2.0 Semester Hrs.
(I, II, S) This course describes the fundamentals of mine environmental and social evaluations and controls, including mine permitting, compliance, impact assessment and analysis and the development of effective environmental and social management systems. The course will stress the execution of these elements in a culturally appropriate manner and the risk to project continuity and corporate reputation if these fundamentals are mishandled. Sustainability and project life cycle aspects will be integrated throughout the course. 2 hours lecture; 2 semester hours.

MNGN563. PM - WATER WASTE AND MINE CLOSURE. 3.0 Semester Hrs.
(I, II) The course addresses the fundamentals and future trends in water and waste management and the design and implementation of mine closure techniques. Emphasis will be placed on the environmental, social, and cost control risks. Topics covered include: 1) water supply, disposal and treatment, 2) site-wide water management, 3) mine waste rock management, 4) process waste and tailings management, 5) solid, hazardous and medical waste disposal, 6) closure design (conceptual to construction-ready), and 7) post-closure elements. The importance of effective water and waste management practices, as well as integrating closure planning techniques into engineering designs, will be stressed throughout the project life cycle. 3 hours lecture; 3 semester hours.

MNGN565. MINE RISK MANAGEMENT. 3.0 Semester Hrs.
(II) Fundamentals of identifying, analyzing, assessing and treating risks associated with the feasibility, development and operation of mines. Methodologies for identifying, assessing and treating risks will be presented and practiced in case studies and exercises. Concepts and principles for analyzing risks will be demonstrated and practiced utilizing deterministic and stochastic models, deductive models, decision trees and other applicable principles. 3 hours lecture; 3 semester hours.

MNGN567. SUSTAINABLE DEVELOPMENT AND EARTH RESOURCES. 3.0 Semester Hrs.
(II) Earth resource industries are increasingly being called on to contribute to sustainable development in the communities and regions in which they take place. In this graduate level course, students will develop an understanding and appreciation of the ways in which resource extraction projects can contribute to sustainable development. The course will be framed around the UN Sustainable Development Goals and will include the following elements: 1) examination of sustainable development principles relevant to mining and energy projects and current best practices and continuing challenges; 2) critical assessment of necessary elements of corporate social responsibility policies and practices; 3) evaluation of stakeholder roles and specify strategies for effective stakeholder engagement; 4) identification of criteria for engineering and management that contribute to sustainable development; and 5) evaluation of real cases that demonstrate where social license to operate was either gained/maintained or not granted/withdrawn. ?.
MNGN570. SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY. 3.0 Semester Hrs.
(I) Fundamentals of managing occupational safety and health at a mining operation. Includes tracking of accident and injury statistics, risk management, developing a safety and health management plan, meeting MSHA regulatory requirements, training, safety audits and accident investigations. 3 hours lecture; 3 semester hours.

MNGN571. ENERGY, NATURAL RESOURCES, AND SOCIETY. 3.0 Semester Hrs.
(I) This is a graduate course that applies a social science lens to understanding the intersections between energy and mineral developments and communities. In this seminar-style course, we will examine these intersections through a case study approach that includes directed readings, such as ethnographies and peer-reviewed journal articles, and that incorporates student-led discussions and research projects. By exploring various development initiatives, such as oil and gas, mining, wind, solar, nuclear, and hydropower, students will gain a comprehensive understanding of the energy-mineral-society nexus and the role communities play in both furthering and limiting these developments. 3 hours lecture; 3 semester hours.

MNGN575. HEAT MINING. 3.0 Semester Hrs.
(I) Heat Mining focuses on identifying available sub-surface heat sources. Heat trapped in crystalline rock deep underground is available by engineering an artificial geothermal system. Hot geothermal fluid, heat generated by underground coal fire and hot water trapped in abandoned underground mine are some of other examples. We will discuss how to find them, how to estimate them, and how to extract and convert them to a usable energy form. The concept of sustainable resource development will be taught as the foundation of heat mining. Prerequisites: None. 3 hours lecture; 3 semester hours.

MNGN585. MINING ECONOMICS. 3.0 Semester Hrs.
(I) Advanced study in mine valuation with emphasis on revenue and cost aspects. Topics include price and contract consideration in coal, metal and other commodities; mine capital and operating cost estimation and indexing; and other topics of current interest. Prerequisite: MNGN427 or EBN504 or equivalent. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN590. MECHANICAL EXCAVATION IN MINING. 3.0 Semester Hrs.
(II) This course provides a comprehensive review of the existing and emerging mechanical excavation technologies for mine development and production in surface and underground mining. The major topics covered in the course include: history and development of mechanical excavators, theory and principles of mechanical rock fragmentation, design and performance of rock cutting tools, design and operational characteristics of mechanical excavators (e.g. continuous miners, roadheaders, tunnel boring machines, raise drills, shaft borers, impact miners, slotters), applications to mine development and production, performance prediction and geotechnical investigations, costs versus conventional methods, new mine designs for applying mechanical excavators, case histories, future trends and anticipated developments and novel rock fragmentation methods including water jets, lasers, microwaves, electron beams, penetrators, electrical discharge and sonic rock breakers. Prerequisite: Senior or graduate status. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN598. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MNGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MNGN625. GRADUATE MINING SEMINAR. 1.0 Semester Hr.
(I, II) Discussions presented by graduate students, staff, and visiting lecturers on research and development topics of general interest. Required of all graduate students in mining engineering every semester during residence. 1 semester hour upon completion of thesis or residence.

MNGN698. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MNGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MNGN700. GRADUATE ENGINEERING REPORTMASTER OF ENGINEERING. 1-6 Semester Hr.
(I, II) Laboratory, field, and library work for the Master of Engineering report under supervision of the student?s advisory committee. Required of candidates for the degree of Master of Engineering. Variable 1 to 6 hours. Repeatable for credit to a maximum of 6 hours.

MNGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.