Mining Engineering

Degrees Offered

- Graduate Certificate in Tailings Engineering
- Professional Masters Program in Mining Industry Management
- Master of Science in Mining Engineering (thesis or non-thesis)
- Master of Science in Earth Resources Science and Engineering (thesis or non-thesis)
- Doctor of Philosophy in Mining Engineering
- Doctor of Philosophy in Earth Resources Science and 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 toward 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 Science and 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 on subject areas.

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
- Extractive and chemical metallurgy for metals processing and recovery
- Tailings and mine waste
- 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 requires 30 credits of coursework and 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 credits of graduate coursework toward the credits 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 credits of the 21-credit requirement from within the Mining Engineering Department. These must include the core requirement courses listed below, unless waived by the master's thesis committee.

Master of Science - Non-thesis (MS-NT)

Students in the Mining Engineering MS-NT program must take a minimum of 21 credits of coursework from within Mining Engineering Department. These must include the core requirement courses listed below unless waived.

Mines' Combined Undergraduate/Graduate Degree Program

Students enrolled in Mines' combined undergraduate/graduate program may double count up to 6 credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with B- or better, not be substitutes for required coursework, and meet all other university, department, and program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

Doctor of Philosophy

Maximum of 48 semester credits of coursework is required. A maximum of 30 units can be transferred from an MS degree program. The student's graduate committee must approve the transfer of these units.

A minimum of 18 credit courses must be taken in the Mining Engineering Department.

Coursework credits (minimum)	48.0
Research credits (minimum)	24.0
Credits beyond the BS degree (required)	**72.0**

Other PhD Requirements

- A minimum of 18 hours of coursework must be completed at 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 credits of coursework towards the coursework 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 ppproval.
- Comprehensive Exams, oral mandatory, and 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
MNGN625	GRADUATE MINING SEMINAR	1.0

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 webpage at https://mining.mines.edu/graduate-program/.

Earth Resources Science and Engineering Program Description

The Earth Resources Science and Engineering specialty is for those who wish to specialize in interdisciplinary fields that include understanding emerging technical and social issues in Earth Resources Science and Engineering . This specialty is open to students with undergraduate degrees in mining, science backgrounds and engineering disciplines 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, tailings and mine waste, 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 Science and 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 credits of graduate coursework toward the required credits for the PhD degree. The doctoral dissertation must be successfully defended before the approved doctoral committee.

Earth Resource Science and Engineering (ERSE) Degree Requirements

Master of Science – Thesis (MS-T)

Students in the ERSE MS-T program must take a minimum of 15 credits from within the Mining Engineering Department. These must include the required core courses listed below unless waived by the master's thesis committee.

Coursework credits (minimum)	21.0
Research credits (maximum)	9.0
Total credits (minimum)	**30.0**

Master of Science - Non-Thesis (MS-NT)

Students in the ERSE MS-NT program must take a minimum of 15 credits of coursework from within Mining Engineering Department. These must include the required core courses listed below unless waived.

Total course work credits (minimum)	**30.0**

Mines' Combined Undergraduate/Graduate Degree Program

Students enrolled in Mines’ combined undergraduate/graduate program may double count up to 6 credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with B- or better, not be substitutes for required coursework, and meet all other university, department, and program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

Doctor of Philosophy

Maximum of 48 semester credits of coursework, where 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 9 credit courses must be taken in the Mining Engineering Department. These must include the required core courses listed below unless waived.

Coursework credits (minimum)	48.0
Research credits (minimum)	24.0
Credits beyond the BS degree (required)	**72.0**

Other PhD Requirements

- A minimum of 18 hours of coursework must be completed at 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 credits of coursework toward the coursework 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, and written may be waived at the discretion of the doctoral committee.

Required Core Courses for either the MS or PhD degree:

The following courses are required:

MNGN510	FUNDAMENTALS OF MINING AND MINERAL RESOURCE DEVELOPMENT	3.0
MNGN625	GRADUATE MINING SEMINAR	1.0

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

MNGN567	SUSTAINABLE DEVELOPMENT AND EARTH RESOURCES	3.0
MNGN556	MINE WATER AND ENVIRONMENT	3.0
MNGN502	GEOSPATIAL BIG DATA ANALYTICS	3.0
MNGN528	MINING GEOLOGY	3.0
MNGN541	ELECTROMETALLURGY	3.0
MNGN542	HYDROMETALLURGY	3.0
MNGN527	SOLID WASTE MINIMIZATION AND RECYCLING	3.0

Prerequisites

Students entering the ERSE 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 webpage at https://mining.mines.edu/graduate-program/.

Professional Master's in Mining Industry Management (MP-MIM) Program Description and Degree Requirements

The PM in Mining Industry Management is being offered fully online. It is not offered on campus. It is a unique and competitive degree offering that stands alone among graduate mining engineering programs (as well as MBA programs) at domestic and international institutions. This new degree does not replace existing graduate programs that focus on technical development and research, but provides a unique choice for students with managerial and business aspirations to obtain an advanced education in the mining and mineral industries. As a fully online graduate program, the PM is not offered on campus. It is open to anyone who has a bachelor’s degree plus at least five years of experience in the mining sector. There is no premium cost for students who reside outside Colorado or outside the United States, and this program does not require students to ever travel to the Mines campus. Students accepted into the program join a cohort, which has the opportunity to take all the program courses in sequence over a two and a half-year period. See https://mining.mines.edu/professionalmasters/ for more information. Graduates from the program will be offered the opportunity to attend commencement ceremony where their degree will be conferred upon them. Online delivery will give the program a competitive edge by offering the flexible schedule necessary to attract professionals in full-time employment or others that cannot leave their place of residence.

The PM curriculum content was developed by Mining Engineering and adjunct faculty, based on discussions with the Mining Engineering department’s industry advisory committee, education professionals, and members of the mining industry.

The curriculum includes 15 courses (3 of which comprise the independent capstone project - MNGN572A-C) encompassing 33 credits. Course content is guided by the vision and values of Mines and the Mining Engineering Department.

The following PM courses are designated with priority registration for students enrolled in the online Professional Master's in Mining Industry Management program. If a student would like to take a particular PM course and is not enrolled in the PM program, they should send an email to PM-MIM@mines.edu requesting approval to take the course. Acceptance into the courses will be based on capacity and consent of instructor.

MNGN553	MINE DESIGN AND OPERATION PLANNING	3.0
MNGN548	INFORMATION TECHNOLOGIES FOR MINING SYSTEMS	3.0
MNGN547	GEOLOGY AND MINING	3.0
MNGN558	MINERAL PROCESSING	3.0
MNGN546	MINE HEALTH AND SAFETY	2.0
MNGN562	MINING ENVIRONMENTAL AND SOCIAL RESPONSIBILITY	2.0
MNGN563	WATER WASTE AND MINE CLOSURE	3.0
MNGN551	MINE ACCOUNTING	2.0
MNGN554	MINE FINANCE	2.0
MNGN557	MINERAL ECONOMICS AND POLICY	2.0
MNGN561	PROJECT MANAGEMENT	3.0
MNGN555	MINE INVESTMENT EVALUATION	3.0
MNGN572A	MINING INDUSTRY MANAGEMENT CAPSTONE DESIGN	0.5
MNGN572B	MINING INDUSTRY MANAGEMENT CAPSTONE DEVELOPMENT	0.5
MNGN572C	MINING INDUSTRY MANAGEMENT CAPSTONE DELIVERY - FINAL SECTION	1.0
Total Semester Hrs		**33.0**

The program was developed to meet the world's evolving challenges related to the Earth, energy, and the environment, and to address the needs of the world's growing population to recover and conserve the Earth's resources. The curriculum confirms Colorado School of Mines as an internationally recognized leader in engineering education, by providing a unique educational experience that collaborates with industry to prepare graduates for leadership in the mining and mineral industries.

Based on the faculty's assessment of the changes in emerging technical, social, and economic factors present in developing a mineral resource, the Colorado School of Mines curriculum should remain the product of choice for domestic and international professional education for the mining industry.

Graduate Certificate in Tailings Engineering

Tailings Engineering specialty is for those who wish to specialize in interdisciplinary fields that include understanding emerging technical and social issues in this discipline. 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, geology, geotechnical engineering, water, soil mechanics, tailing valorization, mineral processing and extractive metallurgy, environmental engineering, and social governance.

Because of the interdisciplinary nature of this degree program, students will be required to take two required courses in the Department of Mining Engineering and then choose two courses related to their area of interest offered by mining, as well as other departments across campus. The certificate program can be completed by taking 12 credits of graduate coursework.

REQUIRED COURSES:		
MNGN581	FUNDAMENTALS OF TAILINGS ENGINEERING I	3.0
MNGN582	FUNDAMENTALS OF TAILINGS ENGINEERING II	3.0

Electives

Please select two courses from the following list of Elective Clusters:

Mining/Mineral Processing & Extractive Metallurgy		
MNGN532	PARTICULATE MATERIAL PROCESSING I - COMMINUTION AND PHYSICAL SEPARATIONS	3.0
MNGN541	ELECTROMETALLURGY	3.0
MNGN542	HYDROMETALLURGY	3.0
MNGN563	WATER WASTE AND MINE CLOSURE	3.0
MNGN556	MINE WATER AND ENVIRONMENT	3.0
Civil & Environmental Engineering		
CEEN515	HILLSLOPE HYDROLOGY AND STABILITY	3.0
CEEN519	RISK ASSESSMENT IN GEOTECHNICAL ENGINEERING	3.0
CEEN581	WATERSHED SYSTEMS MODELING	3.0
CEEN573	RECLAMATION OF DISTURBED LANDS	3.0
Geochemistry		
CHGC503	INTRODUCTION TO GEOCHEMISTRY	3.0
CHGC504	METHODS IN GEOCHEMISTRY	3.0
CHGC508	ANALYTICAL GEOCHEMISTRY	3.0
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
Geophysics		
GPGN530	APPLIED GEOPHYSICS	3.0
GPGN570	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
ESG		
MNGN503	MINING TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT	3.0
MNGN562	MINING ENVIRONMENTAL AND SOCIAL RESPONSIBILITY	2.0
MNGN567	SUSTAINABLE DEVELOPMENT AND EARTH RESOURCES	3.0
MNGN571	ENERGY, NATURAL RESOURCES, AND SOCIETY	3.0
Geological Engineering		
GEGN542	ADVANCED DIGITAL TERRAIN ANALYSIS	3.0
GEGN573	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEGN580	APPLIED REMOTE SENSING FOR GEOENGINEERING AND GEOSCIENCES	3.0
GEGN582	INTEGRATED SURFACE WATER HYDROLOGY	3.0

Course substitutions require the approval of the Tailings Engineering graduate certificate program director.

Courses

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.

MNGN502. GEOSPATIAL BIG DATA ANALYTICS. 3.0 Semester Hrs.
Spatial data models (vector and raster data) and structures (R tree and octree data structures), characteristics of geospatial big data (e.g. satellite images, Lidar point clouds, sensor measurements, environmental monitoring data, socio-economic data), geospatial big data sources (IoT, sensors, images, Lidar, crowd-sources), geospatial big data life cycle, visualizations for geospatial big data sets, isual design principles (Bertin`s visual variables, preattentive attributes, Gestalt principles and Tufte`s design principles), the first order and second order exploration methods for various geospatial data (spatially discrete point data, spatially continuous point data and area data), machine learning algorithms (k-means clustering, self-organizing maps, support vector machines), statistical learning methods (point pattern analyses, kriging, non-spatial, spatial regression and geographically weighted regression).
Course Learning Outcomes

- Recognize main features of spatial data models (vector and raster data) and structures (R tree and octree data structures), recall the characteristics of geospatial big data and evaluate and compare various data sets (e.g. satellite images, Lidar point clouds, sensor measurements, environmental monitoring data, socio-economic data) in terms of the 5V`s (Volume, Velocity, Veracity, Variety and Value) of big data.
- Distinguish types of geospatial big data and its sources (IoT, sensors, images, Lidar, crowd-sources, etc.) in geosciences

- Apply incremental steps of geospatial big data life cycle to a given business case (e.g., monitoring land use and land cover change, decision making processes in geosciences, monitoring human behavior, etc.)
- Design at least three data visualizations for geospatial big data sets considering visual design principles (Bertin`s visual variables, preattentive attributes, Gestalt principles and Tufte`s design principles).
- Implement the first order and second order exploration methods for various geospatial data (spatially discrete point data, spatially continuous point data and area data)
- Apply machine learning algorithms (k-means clustering, self-organizing maps, support vector machines) to geospatial data sets.
- Implement statistical learning methods (point pattern analyses, kriging, non-spatial, spatial regression and geographically weighted regression) to geospatial data sets and identify the structure of big data frameworks used in management of the geospatial big data in geosciences

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.

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, tunneling method and equipment options and system selection for projects with realistic constraints, underground excavation initial support and final lining design, and approaches to uncertainty evaluation and risk assessment for underground construction projects. Team design projects and presentations will be required. Prerequisites: CEEN312 or MTGN321. Corequisites: GEGN462 or GEGN561.

Course Learning Outcomes

- Know the typical application of the underground space, Be aware of subsurface constraints and controlling parameters, be able select project alignments, and understand the pros and cons of different subsurface conditions.
- Develop the ability to design a preliminary geotech site investigation plan, including the boring, as well as field and lab testing, along with the estimated costs.
- Be able to select tunneling method based on results of geotech investigation, have the practical knowledge of various tunneling methods in rock and variety of equipment, and operational settings in the tunneling projects.
- Understand the ground stresses, ground/support reaction curves, and be able to select and develop a preliminary design for ground support in rock.
- Be able to select the shaft and raise development methods in rock for different subsurface conditions.
- Be able to select the right application for conventional tunneling methods, develop blast round design for tunnel.
- know the options, pros and cons, and approaches to Sequential Excavation Method (SEM or NATM).
- Ability to select the right tunnel boring machine (TBM) for the given project and be able to estimate the penetration and daily advance rate.
- Be able to make an assessment of the potential for ground squeezing and rock burst in deep tunnels.
- Be able to offer a preliminary estimate of construction cost for tunnel, and develop a risk registry for rock tunnels.

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.
Course Learning Outcomes

- Not Changing

MNGN509. CONSTRUCTION ENGINEERING AND MANAGEMENT. 3.0 Semester Hrs.
Equivalent with GOGN506,
(II) The course will provide content, methods and experience in construction planning and cost estimating, scheduling and equipment performance, contractual delivery systems and relationships, key contract clauses, risk registration and management, and project controls. Special attention will be paid to geotechnical uncertainty and risk, emerging technologies and industry trends, and to ethics and sustainability as applied to construction engineering and management practices. Co-requisites: GEGN561. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Identify all phases of a construction project from cradle to grave
- Understand the numerous roles and responsibilities of the key project players through all stages of a project, including regulatory framework
- Analyze the advantages and disadvantages of project delivery methods and select the appropriate one for a specific construction project, including environmental and social impacts
- Complete a cost estimate for a tunnel project
- Compete in a construction bid scenario
- Schedule a series of construction tasks using the critical path method
- Establish a project cash flow projection
- Identify and apply key construction contract clauses
- Identify and analyze project risks, with an accent on geotechnical risk
- Identify and assess safety and its management on underground construction projects
- Assess and manage social and ethical issues for underground construction projects

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. Prerequisites: MATH111, MATH112.

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

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

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

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

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

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

MNGN518. ADVANCED BULK UNDERGROUND MINING TECHNIQUES. 3.0 Semester Hrs.
This course will provide advanced knowledge and understanding of the current state-of-the-art in design, development, and production in underground hard rock mining using bulk-mining methods. Design and layout of sublevel caving, block caving, open stoping and blasthole stoping systems. Equipment selection, production scheduling, ventilation design, and mining costs. Prerequisites: MNGN314, MNGN516. 2 hours lecture, 3 hours lab; 3 semester hours. Spring of odd years.

MNGN519. ADVANCED SURFACE COAL MINE DESIGN. 3.0 Semester Hrs.
(II) Review of current manual and computer methods of reserve estimation, mine design, equipment selection, and mine planning and scheduling. Course includes design of a surface coal mine for a given case study and comparison of manual and computer results. Prerequisite: MNGN312, 316, 427. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in odd years.

MNGN520. ROCK MECHANICS IN UNDERGROUND COAL MINING. 3.0 Semester Hrs.
(I) Rock mechanics consideration in the design of room-and-pillar, longwall, and shortwall coal mining systems. Evaluation of bump and

outburst conditions and remedial measures. Methane drainage systems. Surface subsidence evaluation. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN521. EXTRACTIVE METALLURGY OF COPPER, GOLD AND SILVER. 3.0 Semester Hrs.
The same as MTGN-528 Practical applications of fundamentals of chemical-processing-of-materials to the extraction of gold, silver and copper. Topics covered include: History; Ore deposits and mineralogy; Process Selection; Hydrometallurgy and leaching; Oxidation pretreatment; Purification and recovery; Refinement; Waste treatment; and Industrial examples. Prerequisite: Graduate student or senior in good standing.
Course Learning Outcomes

- The same as MTGN-528

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

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

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

MNGN525. INTRODUCTION TO NUMERICAL TECHNIQUES IN ROCK MECHANICS. 3.0 Semester Hrs.
(I) Principles of stress and infinitesimal strain analysis are summarized, linear
constitutive laws and energy methods are reviewed. Continuous and laminated models of stratified rock masses are introduced. The general concepts of the boundary element and finite element methods are discussed. Emphasis is placed on the boundary element approach with displacement discontinui ties, because of its relevance to the modeling of the extraction of tabular mineral bodies and to the mobilization of faults, joints, etc. Several practical problems, selected from rock mechanics and subsidence engineering practices, are treated to demonstrate applications of the techniques. Prerequi site: MNGN321, EGGN320, or equivalent courses, MATH455. 3 hours lecture; 3 semester hours. Offered in even years.

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

MNGN527. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.
(II) Industrial case-studies, on the application of engineering principles to minimize waste formation and to meet solid waste recycling challenges. Proven and emerging solutions to solid waste environmental problems, especially those associated with metals. Prerequisites: ESGN500 and ESGN504.

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.

MNGN531. THERMODYNAMICS OF METALLURGICAL AND MATERIALS PROCESSING. 3.0 Semester Hrs.
Application of thermodynamics to the processing of metals and materials, with emphasis on the use of thermodynamics in the development and optimization of processing systems. Focus areas will include entropy and enthalpy, reaction equilibrium, solution thermodynamics, methods for analysis and correlation of thermodynamics data, thermodynamic analysis of phase diagrams, thermodynamics of surfaces, thermodynamics of defect structures, and irreversible thermodynamics. Attention will be given to experimental methods for the measurement of thermodynamic quantities. Prerequisite: MTGN351.

MNGN532. PARTICULATE MATERIAL PROCESSING I - COMMINUTION AND PHYSICAL SEPARATIONS. 3.0 Semester Hrs.
An introduction to the fundamental principles and design criteria for the selection and use of standard mineral processing unit operations in comminution and physical separation. Topics covered include: crushing (jaw, cone, gyratory), grinding (ball, pebble, rod, SAG, HPGR), screening, thickening, sedimentation, filtration and hydrocyclones. Two standard mineral processing plant-design simulation software (MinOCad and JK SimMet) are used in the course. Prerequisite: Graduate or Senior in good- standing.

MNGN533. PARTICULATE MATERIAL PROCESSING II - APPLIED SEPARATIONS. 3.0 Semester Hrs.
An introduction to the fundamental principles and design criteria for the selection and use of standard mineral processing unit operations in applied separations. Topics covered include: photometric ore sorting,

magnetic separation, dense media separation, gravity separation, electrostatic separation and flotation (surface chemistry, reagents selection, laboratory testing procedures, design and simulation). Two standard mineral processing plant-design simulation software (MinOCad and JK SimMet) are used in the course. Graduate or Senior in good-standing.

MNGN534. ADVANCED IRON AND STEELMAKING. 3.0 Semester Hrs.
Physicochemical principles of gas-slag-metal reactions applied to the reduction of iron ore concentrates and to the refining of liquid iron to steel. The role of these reactions in reactor design, blast furnace and direct iron smelting furnace, pneumatic steelmaking furnace, refining slags, deoxidation and degassing, ladle metallurgy, alloying, and continuous casting of steel. Prerequisites: DCGN209 or MTGN351.

MNGN535. PYROMETALLURGICAL PROCESSES. 3.0 Semester Hrs.
Detailed study of a selected few processes, illustrating the application of the principles of physical chemistry (both thermodynamics and kinetics) and chemical engineering (heat and mass transfer, fluid flow, plant design, fuel technology, etc.) to process development.

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.

MNGN537. EXTRACTIVE METALLURGY OF COPPER, GOLD AND SILVER. 3.0 Semester Hrs.
Practical applications of fundamentals of chemical-processing-of-materials to the extraction of gold, silver and copper. Topics covered include: History; Ore deposits and mineralogy; Process Selection; Hydrometallurgy and leaching; Oxidation pretreatment; Purification and recovery; Refinement; Waste treatment; and Industrial examples. Prerequisite: Graduate or Senior in good-standing.

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.

MNGN541. ELECTROMETALLURGY. 3.0 Semester Hrs.
Electrochemical nature of metallurgical processes. Kinetics of electrode reactions. Electrochemical oxidation and reduction. Complex electrode reactions. Mixed potential systems. Cell design and optimization of electrometallurgical processes. Batteries and fuel cells. Some aspects of corrosion.

MNGN542. HYDROMETALLURGY. 3.0 Semester Hrs.
Kinetics of liquid-solid reactions. Theory of uniformly accessible surfaces. Hydrometallurgy of sulfide and oxides. Cementation and hydrogen reduction. Ion exchange and solvent extraction. Physicochemical phenomena at high pressures. Microbiological metallurgy.

MNGN543. PRINCIPLES OF MATERIALS PROCESSING REACTOR DESIGN. 3.0 Semester Hrs.
Review of reactor types and idealized design equations for isothermal conditions. Residence time functions for nonreacting and reacting species and its relevance to process control. Selection of reactor type for a given application. Reversible and irreversible reactions in CSTR's under nonisothermal conditions. Heat and mass transfer considerations and kinetics of gas-solid reactions applied to fluo-solids type reactors. Reactions in packed beds. Scale up and design of experiments.
Brief introduction into drying, crystallization, and bacterial processes. Examples will be taken from current metallurgical practice.

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. MINE HEALTH AND SAFETY. 2.0 Semester Hrs.
This course focuses behaviors into a culture of safety and health consciousness is a significant management challenge, particularly in the developing world. The topics include: 1) organizational culture and behavior management, 2) strategic safety planning, 3) hazard recognition, 4) root cause analysis, 5) incident management and emergency preparedness, and 6) training programs. Learning emphasis will be balanced among fundamentals, future trends and risk depending on the specific discussion topic. The frequency of training and refresher programs throughout the project life cycle will be addressed. The importance of a health and safety culture transcending the workplace through mine employees into their families, neighbors and communities will also be discussed. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters Mining Engineering and Management Program.
Course Learning Outcomes

- 1. Understand the importance of establishing an organization-wide culture of health and safety and will
- 2. Understand the processes and techniques for effecting changes in human behavior
- 3. Understand the elements of strategic safety planning

- 4. Understand the elements and processes for accident recognition, investigation, analysis and prevention
- 5. Understand the processes and techniques for responding to crisis and emergency situations
- 6. Understand how to design, set up and manage health and safety training programs that are tailored to specific project needs.

MNGN547. GEOLOGY AND MINING. 3.0 Semester Hrs.
This course focuses on how the ore deposit geology, structure, resource assessment and geochemistry are inextricably linked to major project decisions and cost control regarding mining methods and water management. The course emphasizes fundamentals of exploration, geosystem characterization, and the risks associated with failure to integrate these aspects into decision making. Major topics include: 1) ore genesis, 2) exploration methods, 3) geostatistics and resource development, 4) geologic hazards, 5) geochemistry and geo environmental considerations, 6) groundwater (further addressed in Water, Waste and Closure course), and 7) geologic factors for consideration in mine design. The importance and cost efficiency of collecting and managing data concurrent with its generation will be emphasized. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters Mining Engineering and Management Program.
Course Learning Outcomes

- 1. Students will describe various principal ore genesis events and relationships with local and regional geology.
- 2. Students will assess the relationship between ore deposits and mine planning activities.
- 3. Students will formulate exploration programs.
- 4. Students will formulate sampling and data validation (EDA) requirements, and identify geostatistical assessment requirements required by JORC and NI 43-101 documents.
- 5. Students will identify the parameters required to minimize risks associated with geological structures, resource evaluation and mine planning.

MNGN548. INFORMATION TECHNOLOGIES FOR MINING SYSTEMS. 3.0 Semester Hrs.
This course will focus on the role of information systems (IS) for specific mining systems in the mine life cycle. We will look at various data sources and acquisition methods like internet-of-things, crowdsourcing, and blockchain. Management of data is the principal function of an IS, so we will look at the main features and functions of a database management system (DBMS). Due to the exponential growth of unstructured data, the integration of structured data sets managed in a DBMS with big data infrastructures, which are mainly unstructured, and will be another focus of the course. Geographic Information Systems (GIS) will be introduced for managing spatial and tabular data. Advancements in sensor technologies allow the various remote sensing (RS) products to be integrated with GIS in various mining systems. The fundamental principles of design visualizations will also be explored. The IS in various full/semi-autonomous mining systems will be covered, and we will analyze the methods of interoperability and related infrastructures. We will identify cybersecurity issues related to autonomous mining systems and future trends. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters - Mining Engineering and Management Program.
Course Learning Outcomes

- 1. Students will design and evaluate mining support facilities, and utilities.
- 2. Students will design top-level communication, control and monitoring systems.
- 3. Students will construct mine operations databases, perform queries, and evaluate outcomes.
- 4. Students will evaluate mine plant systems for cost, environmental compliance, risk, and life-of-project sustainability.
- 5. Students will formulate, evaluate, and present design alternatives for a mine plant project.

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

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

MNGN551. MINE ACCOUNTING. 2.0 Semester Hrs.
Accounting is the process of recording business transactions. Financial analysis uses accounting information to gain insights into the financial position, performance, and prospects of a company. This course aims at building the accounting and financial knowledge and skills to allow students to participate in decision-making, financial, and corporate management processes. The objective is to make better managers and leaders by developing practical knowledge and abilities to interpret financial statements, evaluate a competitive position from the financial perspective, and determine the financial implications of business decisions. This is exclusively an online course that is cohort-based with limited enrollment. It is offered specifically for the Professional Masters Program in Mining Engineering and Management.
Course Learning Outcomes

- 1. Students will be knowledgeable of principles of accounting as applicable to engineers and managers in the mining industry.
- 2. Students will understand and be able to evaluate financial statements and balance sheets.
- 3. Students will understand the application of cost accounting methods for mine projects and operations including the proper application of accruals.
- 4. Students will understand accounting standards in the U.S. and internationally from a managerial perspective.
- 5. Students will be aware of mandatory financial reporting requirements for corporate entities in the U.S.

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. MINE DESIGN AND OPERATION PLANNING. 3.0 Semester Hrs.
This course provides an overview of mine design and operations fundamentals with a focus on the future trends which considers where the industry will be in the next decade(s). Topics give an over-arching significance to social, environmental, health and safety considerations in traditional design and operations decision-making. Principal topics will include 1) mining methods and planning, 2) production scheduling and optimization, 3) robotics and automation, 4) equipment capabilities and selection processes, 5) mine ventilation, 6) rock mechanics and ground control, and 7) waste disposal (high level, further addressed in Water, Waste and Closure course). Project life cycle and sustainability principles will be applied throughout the course content. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters Mining Engineering and Management Program.
Course Learning Outcomes

- 1. Students will specify underground and surface mining methods that can optimally exploit a mineral resource based on its chemical and physical characteristics.
- 2. Students will prepare mine production schedules that can provide desired cash flows based on ore production and waste disposal.
- 3. Students will evaluate emerging technologies to improve health and safety, and improve productivity.
- 4. Students will design mine ventilation plans to effectively provide the desired working atmosphere.
- 5. Students will characterize local geological conditions to design a ground control plan.
- 6. Students will develop a sustainable waste disposal plan to comply with government regulations and social concerns.
- 7. Students will assess risks and develop plans to mitigate and manage risks.

MNGN554. MINE FINANCE. 2.0 Semester Hrs.
This course describes the finance principles applicable to the mining industry. It addresses the practical application of these principles to a level of detail appropriate for a manager or corporate executive to understand what it takes to raise money in the international marketplace to finance a corporate entity or a specific mining project. This is exclusively an online course that is cohort-based with limited enrollment. It is offered specifically for the Professional Masters Program in Mining Engineering and Management.
Course Learning Outcomes

- 1. Students will be knowledgeable of principles of finance as applicable to engineers and managers in the mining industry.
- 2. Students will be aware and understand various financing methods for establishing corporate equity and for funding specific mine projects.
- 3. Students will understand the fundamentals of asset and cash management in a mining venture.
- 4. Students will be aware of approaches and challenges of mergers and acquisitions.
- 5. Students will be aware of the financial challenges and potential remedies throughout the mine life cycle from exploration to closure.
- 6. Students will know how to apply financial ratios in analyzing a mining company's financial health.
- 7. Students will be aware of the purposes and protocols for audits.

MNGN555. MINE INVESTMENT EVALUATION. 3.0 Semester Hrs.
This course discusses the elements, methods and analyses required to evaluate the viability and robustness of a mining project. Current practices for introducing the uncertain nature of most of the important variables in an investment analysis are addressed. While future trends and risks will be covered, course emphasis will be on the fundamentals of determining the feasibility of a project and the elements contained in a robust financial model to demonstrate that feasibility. Topics include: 1) laws and security exchange expectations for publicly disclosed documents, 2) feasibility study content, 3) responsibilities of the Qualified Person, 4) capital and operating cost estimation, 5) accruals and taxes, 6) financial analysis and cash flow modeling, 7) sensitivity analysis, and 8) public reporting. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters Mining Engineering and Management Program.
Course Learning Outcomes

- 1. Students acquire an advanced knowledge in mine capital investment evaluation utilizing time value of money principles.
- 2. Students are knowledgeable of implications on capital investments of tax policy, sustainability requirements, leasing, debt financing and other forms of capital structure in a project.
- 3. Students acquire knowledge for performing cost estimation for capital and operating cost budgets in feasibility studies.
- 4. Students are knowledgeable of how to prepare and the requirements for feasibility studies at the different levels of detail.
- 5. Students will be aware of world standards for public reporting requirements of mineral resources, reserves and investments.
- 6. Students are knowledgeable of methods of sensitivity and real options evaluation of capital investments.

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.
Course Learning Outcomes

- Predict physical characteristics of a hydrogeological system
- Construct conceptual models of the hydrogeological conditions in a mine setting
- Propose effective methods for management of an abandoned mine
- Describe requirements for mine closure and reclamation

MNGN557. MINERAL ECONOMICS AND POLICY. 2.0 Semester Hrs.
This course is designed to help students learn some of the basic economic principles that will help them better understand mineral

commodity market behavior and the important factors that drive mineral supply, demand, prices and other market elements. The course is designed to help you build the economic, market and policy knowledge and skills to effectively participate in company decision-making and strategic management discussions. It concentrates on the economic factors and principles that mine managers and executives need to recognize, analyze and deal with in order to position their company for long-term success in volatile commodity markets. The overall objective of this course is not to make students mineral economists, but to make them a better managers and leaders by developing a practical understanding of the commodity markets in which they will deal. It will also give them a deeper knowledge of government's perspective and role in the mineral industry. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters Mining Engineering and Management Program.
Course Learning Outcomes

- 1. Students will be knowledgeable of the underlying mineral market dynamics of supply and demand.
- 2. Students will be aware of historical and potential factors that influence the demand and supply of minerals.
- 3. Students will understand the role of public policy in defining the mining industry in a nation including the requirements for tax and royalty revenue, economic contributions and sustainable development of the local and greater communities.

MNGN558. MINERAL PROCESSING. 3.0 Semester Hrs.
This course addresses the fundamentals for developing an appropriate and cost-efficient mineral process for a given ore type and the risks that factor into deploying the selected process. Consideration will be given for the need to demonstrate a proven and robust process to potential investors (a bankable process). Topics will include 1) unit operations and material handling, 2) sampling techniques specific to process considerations, 3) material testing and data organization and management, 4) water and energy considerations, 5) mill design and development (concept through construction), and 6) process waste disposal (high level, further addressed in Water, Waste and Closure course). Timing of process design within the project life cycle will be addressed. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters Mining Engineering and Management Program.
Course Learning Outcomes

- 1. Students will identify and specify mill unit operations that are appropriate for a given ore.
- 2. Students will establish project develop plans from concept through operation.
- 3. Students will estimate the capital and operating cost of mills.
- 4. Students will develop an economic model from concentrate qualities and smelter schedules.
- 5. Students will assess risks and emerging trends in mineral processing systems.
- 6. Students devise mill performance testing programs.
- 7. Students will construct water and energy management plans.

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

MNGN560. INDUSTRIAL MINERALS PRODUCTION. 3.0 Semester Hrs.
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. PROJECT MANAGEMENT. 3.0 Semester Hrs.
This course addresses the many aspects of business and project management. As the business environment changes, mine managers and executives face competing pressures to deliver both profits and effective social, environmental and economic results. Leadership is a fundamental tool for the effective executive. While a solid base of technical and operational skills is required, they must also engage a workforce, build and retain employees and seize opportunities for growth and development. While the course will address future trends and risks, emphasis will be on the fundamentals of effective business and project management. Topics include: 1) leadership, 2) project planning and controls, 3) quality assurance, 4) business process improvement, 5) risk assessment techniques, 6) personnel management and 7) conflict resolution. Because the leadership role is one that goes beyond the workplace, the course will explore the role of the project manager in communications and supporting sustainable investments. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters Mining Engineering and Management Program. Prerequisites: MATH225 and MTGN461 or equivalent.
Course Learning Outcomes

- 1. Students are knowledgeable of all aspects of project management from major mine construction projects to business improvement projects.
- 2. Students are capable of applying improvement tools to boost business results.
- 3. Students are adept at methods for analyzing and managing risk.
- 4. Students understand methods to improve decision-making under conditions of uncertainty.
- 5. Students are capable of applying constraints analysis and using methods to optimize mine systems and processes.
- 6. Students understand when and how to apply various approaches for conflict resolution in the business.

MNGN562. MINING ENVIRONMENTAL AND SOCIAL RESPONSIBILITY. 2.0 Semester Hrs.
This course explores the fundamentals of, and to the extent relevant, the future trends in building environmentally and socially responsible mining projects in the context of the project life cycle. Emphasis will be on 1) host country and international industry regulatory expectations and good practice; 2) communication strategies, stakeholder engagement, and building community support; 3) mining project screening and scoping, 4) characterization of environmental and social media; 5) predicting project-induced environmental and social impacts and identifying plausible mitigating actions to reduce adverse impacts to acceptable levels and

enhance project benefits; and 6) developing and implementing effective social and environmental management systems. Course emphasis will be on executing these fundamentals adequately and in a culturally appropriate manner, and on the risk to project continuity and corporate reputation if these fundamentals are mishandled. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters Mining Engineering and Management Program.

Course Learning Outcomes

- 1. Understand the significance and commonalities of the administrative and regulatory framework in host country jurisdictions and the importance of industry good practices, lender and development bank expectations.
- 2. Understand the fundamentals of the environmental and social assessment process and how it fits into the overall project cycle.
- 3. Understand the business case for social and environmental assessment, including key concepts and the roles and responsibilities of assessment professionals.
- 4. Understand what goes into each procedural step of the assessment process.
- 5. Understand how to limit the scale of the assessment to address only what is needed, no more and no less, so that the resulting environmental and social assessment is cost-efficient, appropriately scaled and fit-for-purpose.
- 6. Understand the need and processes for stakeholder engagement and how it fits with the social and environmental assessment process throughout the project cycle.
- 7. Understand the business case for stakeholder engagement and the roles and responsibilities of assessment professionals.
- 8. Understand the elements of, and continuous improvement processes for, a comprehensive environmental and social management system.

MNGN563. WATER WASTE AND MINE CLOSURE. 3.0 Semester Hrs.

This course addresses three disciplines that are critically important to a successful and sustainable mining project. Beyond the ore deposit, water is essential for all mining projects. Supplies must be balanced among local and regional water users. Closure and reclamation is one phase of the mine life cycle and constitutes a significant mitigating action and cost to mining projects. The course will address fundamentals and future trends, but significant 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 minimization, recycling and disposal, 6) closure design (conceptual to construction-ready), 7) surety estimation and available surety instruments, and 8) post-closure elements including monitoring, maintenance, retrenchment, close-out costs and surety release. 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. This is exclusively an online course that is cohort based with limited enrollment. It is offered specifically for the Professional Masters Mining Engineering and Management Program.

Course Learning Outcomes

- 1. Understand the fundamentals of watershed hydrology and hydrometeorology at mine sites 2. Understand the fundamentals of hydrogeology, including aquifer properties, saturated and unsaturated flow and groundwater quality. 3. Understand mining hydrogeology, mine dewatering systems and the development of the water supply 4. Understand surface water management, sedimentation control and surface water models 5. Understand water balances and models, including facility-specific water balances (e.g., tailings, heap leach facilities) and site-wide water balances 6. Understand hydrology at closure, including pit lakes, underground reservoirs and water treatment 7. Understand the risks associated with mismanagement of mine wastes 8. Understand the applicable guidelines and regulatory framework pertaining to mine wastes. 9. Understand the elements of material characterization, including physical and geochemical characterization 10. Understand the methods and design criteria for heap leaching systems and for the permanent storage of mine waste rock and mill tailings 11. Understand the fundamentals of solid, hazardous and medical waste management 12. Understand slope stability evaluations as they relate to mine waste and closure scenarios 13. Understand the fundamentals of mine closure planning, design and implementation as well as the financial implications

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.

Course Learning Outcomes

- At the conclusion of the class students will… a) Be aware of the types of risks associated with the mining industry b) Be knowledgeable of the systematic risk management process – identification, analysis, assessment and treatment c) Be familiar with concepts and methods used in risk identification, analysis, assessment and treatment d) Be familiar with techniques applied in causative analysis e) Be familiar with quantitative risk analysis methods as applied to the mining industry – decision trees, stochastic modeling, deductive modeling and other applicable principles

MNGN566. INNOV8X. 3.0 Semester Hrs.

Innov8x introduces concepts and tools to accelerate the design, validation and adoption of innovations in support of creative problem solving. Using an entrepreneurial mindset, we learn how to identify and frame problems that beneficiaries and stakeholders face. We attempt to design and test practical solutions to those problems in collaboration with those who experience the problems. We apply beneficiary discovery, pretotyping, business model design (social, economic and environmental), constrained creativity, efficient experimentation, and rapid iteration. While resolving challenges involves technical solutions, an important aspect of this course is directly engaging beneficiaries and stakeholders in social contexts to develop solutions with strong impact potential. Innov8x is grounded in collaborative creativity theory at the intersection of organizational behavior (social psychology), design principles, entrepreneurship and innovation management.

Course Learning Outcomes

- Frame and translate complex ambiguous problems in resources sciences and engineering into actionable opportunities for innovation
- Conduct effective, objective and ongoing beneficiary discovery in efficient ways
- Combine tools and methods to quickly test assumptions and secure beneficiary acceptance

- Develop creative approaches to navigate real and perceived constraints
- Leverage mentor and stakeholder support through credible communication based on research
- Launch innovative solutions with the advocacy of beneficiaries and stakeholders
- Create value by solving complex sociotechnical problems with scientific and technical foundations

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. 2 hours lecture; 3 hours lab; 3 hours total.
Course Learning Outcomes

- Demonstrate knowledge of sustainable development principles relevant to mining and energy projects and identify current best practices and continuing challenges.
- Critically evaluate necessary elements of Corporate Social Responsibility concepts and practices (transparency, accountability, continuous improvement, etc.).
- Determine stakeholder roles in general and for particular projects, and specify strategies for effective stakeholder engagement
- Specify criteria for engineering projects that contribute to sustainable development, and evaluate the “business case” for incorporating such criteria.
- Identify mine management successes in real cases where a social license to operate was gained/maintained, or “fatal flaws” in cases where a social license was not granted/withdrawn; and suggest alternative approaches in unfavorable cases.

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.
Course Learning Outcomes

- Apply critical thinking and interdisciplinary analyses to the relationship between energy and mineral developments and society.
- Research, write about, present, and discuss case studies on the relationship among energy, natural resources, and society in a variety of contexts
- Apply concepts such as, sustainability, community development, corporate social responsibility, and social license to operate to analyses of the energy-natural resources-society nexus

MNGN572A. MINING INDUSTRY MANAGEMENT CAPSTONE DESIGN. 0.5 Semester Hrs.
This is the first of a three-course series to design, develop and deliver a project that will ideally be of value to the student’s employer in his or her current role in the company. The project will be created and done independently by the student, typically in conjunction with his or her existing job. Prerequisite: None Co-requisite: None.
Course Learning Outcomes

MNGN572B. MINING INDUSTRY MANAGEMENT CAPSTONE DEVELOPMENT. 0.5 Semester Hrs.
This is the second of a three-course series to design, develop and deliver a project that will ideally be of value to the student’s employer in his or her current role in the company. The project will be created and done independently by the student, typically in conjunction with his or her existing job. Prerequisite: MNGN571A.
Course Learning Outcomes

- Ability to think through, define and design a project with sufficient detail to allow for detailed project planning and development. Evaluate and communicate clearly a written response to a request for proposal (RFP) from the perspective of a contractor or consultant that encompasses contractor background, project scope and content and a detailed schedule, budget, milestone deliverables, and tasks necessary to complete the project to address client needs. Craft a response to an RFP with specific sensitivity to the target audience and their needs and objectives and also serves as an effective marketing document for contractor/consultant expertise and experience

MNGN572C. MINING INDUSTRY MANAGEMENT CAPSTONE DELIVERY - FINAL SECTION. 1.0 Semester Hr.
This is the final course of a three-course series to design, develop and deliver a project that will ideally be of value to the student’s employer in his or her current role in the company. The project will be created and done independently by the student, typically in conjunction with his or her existing job. Prerequisite: MNGN572B.
Course Learning Outcomes

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.

Course Learning Outcomes

- The following outcomes are expected: understanding of the concept of sustainable heat mining; understanding the state-of-the-art heat recovery and utilization methods; understanding stakeholders

MNGN581. FUNDAMENTALS OF TAILINGS ENGINEERING I. 3.0 Semester Hrs.

This course provides a broad overview of tailings storage facility (TSF) operation and governance. Topics covered include mineral processing and tailings generation (volume vs. commodity produced; tailings physical, mineralogical, and geochemical) characterization; tailings continuum and rheology (including solid-liquid separation, dewatering, thickening, and filtering); introduction to tailings geotechnics; TSF Design and Operations; tailings innovations in the mining industry. Prerequisite: BSc in Mining Engineering, Geosciences, or related fields.

Course Learning Outcomes

- Describe the process in which tailings are generated from ore processing, and contrast tailings production from different mines as a function of commodity;
- Distinguish and compare different types of tailings in terms of physical and chemical/mineralogical characteristics, and develop a logical argument based on the concepts of tailings generation to explain the differences;
- Differentiate tailings based on the rheology of the “tailings continuum” and explain how the factors affecting yield strength and viscosity impact on tailings management;
- Analyze the different technologies applied for water reduction in the context of tailings dewatering, thickening, and filtering;
- Contrast current practices in mine tailings to identify challenges that are pushing innovation in the industry, including demands for tailings minimization, environmental and social impacts, and governance (ESG);
- Explain the importance of integrating the existing mine workings into planning and siting of a tailings facility;
- Apply data / information sources to design an effective site investigation.
- Apply material balance and water balance analysis to TSF initial design, and identify and assess external considerations that influence siting;
- Apply multiple accounts analysis to assess candidate locations for a future tailings facility;
- Design an effective surveillance and monitoring program considering the outcomes from geotechnical investigations;
- Discuss strength and deformation of tailings with emphasis on drained and undrained shear behavior, and describe importance of and methods used for evaluating dilative/contractive and brittle/ductile behavior;
- Describe a framework to connect stress, density, water pressures and shear behavior, and identify common loading conditions in tailings facilities, and identify critical design cross sections; and,
- Apply several methods of geotechnical analyses to evaluate the stability and performance of TSFs.

MNGN582. FUNDAMENTALS OF TAILINGS ENGINEERING II. 3.0 Semester Hrs.

This course provides a framework for engineering design and decisions regarding tailings storage facility (TSF) water systems, multi-stakeholder risk management and operations, and TSF closure. Topics covered include TSF Water Management, TSF Operations and Compliance and TSF Closure and Reclamation. Prerequisite: BSc in Mining Engineering, Civil Engineering, Geosciences or related engineering fields.

Course Learning Outcomes

- Define the role of water in the planning and operation of a TSF.
- Describe the hydrologic processes important to surface water, seepage and groundwater management at TSFs.
- Understand the current practice of addressing climate uncertainty and climate change.
- Analyze the role of the mine water management plan in TSF management and decision making.
- Explain what water balance models are, how they can be used to improve decision making, and what techniques can be implemented to improve model reliability.
- Describe the essential components, risks and generally accepted risk mitigation for the design and operation of TSF water management systems.
- Provide perspective on project management aspects of tailings construction, including managing construction contractors, resident engineering, quality assurance and quality control, and documentation
- Manage development and implementation of an OMS (Operation, Maintenance and Surveillance) systems
- Manage the process of developing EAP (Emergency Action Plans; called Emergency Preparedness and Response Plans in the Global Industry Standard
- Explain and implement applicable international standards of care, including the Global Tailings Standard, the Mining Association of Canada (MAC) guidelines, The Canadian Dam Association (CDA) guidelines and other related references
- Describe the process and components of TSF decommissioning and closure.
- Compare and contrast techniques for minimizing TSF closure challenges via closure-oriented tailings management through life-of-mine.
- Select components and design different cover types for function.
- Prepare closure cost estimates and schedules.
- Compare financial assurance instruments.
- Distinguish between net present value and whole-of-life accounting.
- Develop a TSF closure plan that fits within an integrated site-wide closure plan.

MNGN585. MINING ECONOMICS. 3.0 Semester Hrs.

(I) Advanced study in mine valuation with emphasis on revenue and cost aspects.

Topics include price and contract consideration in coal, metal and other commodities; mine capital and operating cost estimation and indexing; and other topics of current interest. Prerequisite: MNGN427 or EBGN504 or equivalent. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN590. MECHANICAL EXCAVATION IN MINING. 3.0 Semester Hrs.

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

MNGN598. SPECIAL TOPICS IN MINING ENGINEERING. 0-6 Semester Hr.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MNGN598. SPECIAL TOPICS. 1-6 Semester Hr.

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MNGN599. INDEPENDENT STUDY IN MINING ENGINEERING. 0.5-6 Semester Hr.

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

MNGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

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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.

MNGN631. TRANSPORT PHENOMENA IN METALLURGICAL AND MATERIALS SYSTEMS. 3.0 Semester Hrs.

Physical principles of mass, momentum, and energy transport. Application to the analysis of extraction metallurgy and other physicochemical processes.

MNGN698. SPECIAL TOPICS IN MINING ENGINEERING. 0-6 Semester Hr.

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

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.

MNGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

MNGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

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.

Department Head

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H. Sebnem Duzgun

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