METALLURGICAL AND MATERIALS ENGINEERING (MTGN)

MTGN198. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 1-3 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN199. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN202. ENGINEERED MATERIALS. 3.0 Semester Hrs.
Equivalent with SYGN202,
Introduction to the Metallurgical and Materials Engineering paradigm: processing, structure, and properties. The course will relate technologically significant processing procedures to resultant structures. The material structure will be examined to determine its effect upon material properties. Students will study materials engineering methodologies and learn terminology. 3 hours lecture; 3 semester hours. Prerequisite: CHGN121, MATH112, and PHGN100.
Course Learning Outcomes

- No change

MTGN211. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.
Principles of atomic bonding, crystallography, and amorphous structures. ii) Symmetry relationships to material properties. iii) Atomic structure determination through diffraction techniques. 3 hours lecture; 3 semester hours. Prerequisite: MTGN202. Co-requisite: PHGN200.
Course Learning Outcomes

- ABET 1, 5

MTGN219. ART AND SCIENCE OF GLASSBLOWING. 2.0 Semester Hrs.
Explore the science of glass by learning artistic glassblowing. Lectures will cover basic glass network structure, melt processing and viscosity, forming and cold working, as well as optical and mechanical properties. Over the course of the semester, laboratory exercises will train students in basic glassblowing and safe use of a hot glass shop. Students who pass the course with a B or better will be certified to use the Hill Hall hot glass shop during open shop hours. Due to the limited capacity of this course, registration opportunities are determined each semester by a random lottery. Details are announced via the Daily Blast a couple of weeks prior to registration begins. This course is not counted towards MME major completion as an MTGN elective.
Course Learning Outcomes

- ABET #4

MTGN251. METALLURGICAL AND MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.
Applications of thermodynamics in extractive and physical metallurgy and materials science. Thermodynamics of solutions including solution models and thermodynamic properties of alloys and slags. Reaction equilibria with examples in alloy systems and slags. Phase stability analysis. Thermodynamic properties of binary alloys in the solid state, defect equilibrium, and interactions. 3 hours lecture; 3 semester hours. Prerequisite: MATH112, CHGN122 or CHGN125, and PHGN100.
Course Learning Outcomes

- ABET1

MTGN272. MME FIELD SESSION. 3.0 Semester Hrs.
Introduction to the field of Metallurgical and Materials Engineering. Overview of opportunities, expectations, and practices within the MME department and the broader materials community. Introduction to bonding, crystal and grain structure, application space, and Structure-Property-Processing relationships. Laboratory projects and plant visits. Prerequisites: MATH112, PHGN100. 9 hours lab; 3 semester hours.
Course Learning Outcomes

- No change

MTGN281. INTRODUCTION TO PHASE EQUILIBRIA IN MATERIALS SYSTEMS. 2.0 Semester Hrs.
Review of the concepts of chemical equilibrium and derivation of the Gibbs phase rule. Use of thermodynamic principles for constructing and interpreting one, two and three component phase equilibrium diagrams. Application to alloy and ceramic materials systems. Emphasis on the evolution of phases and their amounts and the resulting microstructural development. Prerequisite: MTGN202, MTGN251.
Course Learning Outcomes

- ABET 1

MTGN298. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN298. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN299. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN300. FOUNDRY METALLURGY. 2.0 Semester Hrs.
Design and metallurgical aspects of casting, patterns, molding materials and processes, solidification processes, risers and gating concepts, casting defects and inspection, melting practice, cast alloy selection. 2 hours lecture; 2 semester hours. Co-requisite: MTGN300L.
Course Learning Outcomes

- ABET 3

MTGN300L. FOUNDRY METALLURGY LABORATORY. 1.0 Semester Hr.
Equivalent with MTGN302,
Experiments in the foundry designed to supplement the lectures of MTGN300. 3 hours lab; 1 semester hour. Co-requisite: MTGN300.
Course Learning Outcomes

- ABET 3

MTGN310. POWDER PROCESSING AND FORMING. 2.0 Semester Hrs.
Fabrication of components from powder-based feedstocks is central to both ceramic and metallurgical engineering, and the concepts of powder processing apply to industries as diverse as mining, food products, paints, and many more. This course covers the handling, measurement, and application of powdered feedstocks to the formation of green bodies (i.e., powder compacts) using both wet and dry methods. Particular attention is paid to the importance of powder characteristics, green density, impurities and other defects in these initial stages to the final density, microstructure and overall properties of the subsequent part, whether the parts are sintered or consolidated in another way such as laser powder bed fusion (LPBF). Prerequisite: MTGN202, MTGN251. Co-requisite: MTGN310L.
Course Learning Outcomes

- 1. exhibit basic competence in wet and dry handling of fine powders
- 2. apply both optical and mechanical approaches to the measurement of particle size and distribution and apply both mechanical and fluid-based approaches to particle size sorting
- 3. exhibit basic competence in wet processing of powders and control of rheology through colloidal dispersion and stabilization techniques
- 4. demonstrate powder based forming of a macroscopic component

MTGN310L. POWDER PROCESSING AND FORMING LABORATORY. 1.0 Semester Hr.
Fabrication of components from powder-based feedstocks is central to both ceramic and metallurgical engineering, and the concepts of powder processing apply to industries as diverse as mining, food products, paints, and many more. This course covers the handling, measurement, and application of powdered feedstocks to the formation of green bodies (i.e., powder compacts) using both wet and dry methods. Particular attention is paid to the importance of powder characteristics, green density, impurities and other defects in these initial stages to the final density, microstructure and overall properties of the subsequent part, whether the parts are sintered or consolidated in another way such as laser powder bed fusion (LPBF). Prerequisite: MTGN202, MTGN251. Co-requisite: MTGN310.
Course Learning Outcomes

- 1. exhibit basic competence in wet and dry handling of fine powders
- 2. apply both optical and mechanical approaches to the measurement of particle size and distribution and apply both mechanical and fluid-based approaches to particle size sorting
- 3. exhibit basic competence in wet processing of powders and control of rheology through colloidal dispersion and stabilization techniques
- 4. demonstrate powder based forming of a macroscopic component

MTGN314. PROPERTIES AND PROCESSING OF CERAMICS. 2.0 Semester Hrs.
Application of engineering principles and fundamental structure-processing-property relationship to inorganic non-metallic materials. Emergence of macroscopic characteristics and functional properties from bonding, structure, symmetry, and defects. Applications of basic thermodynamic and kinetic principles to powder-based processing. 2 hours lecture; 2 semester hours. Co-requisite: MTGN314L, MTGN202, and MTGN251.
Course Learning Outcomes

- ABET 1, 6

MTGN314L. PROPERTIES AND PROCESSING OF CERAMICS LABORATORY. 1.0 Semester Hr.
Laboratory for MTGN314. 3 hours lab; 1 semester hour. Co-requisite: MTGN314.
Course Learning Outcomes

- ABET 3

MTGN315. ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS. 3.0 Semester Hrs.
Survey of aspects of modern physics needed to understand selected properties of materials including conductivity (electrical, thermal, etc.), electronic states of materials, density of states, the nature of bands and bonding and how they arise, total and cohesive energy of solids based on filling of states, the nature of metals, semiconductors, and dielectrics and how these arise from electronic states, and the application of these concepts to understand dielectrics, magnetism, and semiconductor devices. Prerequisite: PHGN200, MATH225, MTGN211.
Course Learning Outcomes

- ABET 1, 2, 5

MTGN319. INTRODUCTION TO GLASS SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Introduction to the principles of glass science and engineering and non-crystalline materials. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisite: MTGN202. Co-requisite: MTGN319L.
Course Learning Outcomes

- 1. Understand atomic origins and structure of amorphous solids
- 2. Understand the principles of glass formation from melts
- 3. Understand and engineer the mechanical, optical, transport, and electrical properties of glasses
- 4. Engineer glass materials for biological, optical, and thermal applications

MTGN319L. INTRODUCTION TO GLASS SCIENCE AND TECHNOLOGY LABORATORY. 1.0 Semester Hr.
Introduction to the principles of glass science and engineering and non-crystalline materials. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisite: MTGN202. Co-requisite: MTGN319.
Course Learning Outcomes

- 1. Understand atomic origins and structure of amorphous solids
- 2. Understand the principles of glass formation from melts

- 3. Understand and engineer the mechanical, optical, transport, and electrical properties of glasses
- 4. Engineer glass materials for biological, optical, and thermal applications

MTGN333. INTRODUCTION TO BLADESMITHING. 3.0 Semester Hrs.
An introduction to the metallurgy and art of bladesmithing. The course covers ferrous metallurgy with a focus on tools steels used for creating edged tools. Students will learn and execute techniques for alloy selection, shaping, profiling, beveling, heat treating, and sharpening knives. Students will complete at least two knives, one specified by the instructor, and one of the students own design. Co-requisite: MTGN348 or instructor consent.
Course Learning Outcomes

- ABET a, b, c

MTGN334. CHEMICAL PROCESSING OF MATERIALS. 3.0 Semester Hrs.
Development and application of fundamental principles related to the processing of metals and materials by thermochemical, aqueous, and fused salt electrochemical/chemical routes. The course material is presented within the framework of a formalism that examines the physical chemistry, thermodynamics, reaction mechanisms and kinetics inherent to a wide selection of chemical processing systems. The general formalism provides for a transferable knowledge-base to other systems not specifically covered in the course. Prerequisite: MTGN272 and MTGN251. Co-requisite: MTGN334L.
Course Learning Outcomes

- no change

MTGN334L. CHEMICAL PROCESSING OF MATERIALS LABORATORY. 1.0 Semester Hr.
Experiments in chemical processing of materials to supplement the lectures of MTGN334. 3 hours lab; 1 semester hour. Co-requisite: MTGN334.
Course Learning Outcomes

- ABET 1, 2

MTGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. 1 to 3 semester hours. Cooperative education credit does not count toward graduation except under special conditions. Repeatable.
Course Learning Outcomes

- depends

MTGN345. SINTERING OF CERAMICS. 3.0 Semester Hrs.
This course covers the fundamentals and applications of sintering based processes in ceramic engineering. It includes solid-state, liquid phase, reactive and vapor phase sintering and covers densifying and non-densifying mechanisms as well as microstructure development for bulk, coatings, and additively manufactured parts. The course covers technologies used in the processing of ceramics. Prerequisite: MTGN310, MTGN352, MTGN281. Co-requisite: MTGN345L.
Course Learning Outcomes

- 1. Exhibit a basic understanding of sintering mechanisms in ceramics
- 2. Engineer microstructure development of powder-based specimens from green body to dense polycrystalline ceramics
- 3. Design a thermal profile to produce a desired microstructure for a given material for different processing techniques
- 4. Characterize abnormal grain growth, solute drag, pore drag, and Zener pinning

MTGN345L. SINTERING OF CERAMICS LABORATORY. 1.0 Semester Hr.
This is the laboratory course for MTGN345. This course covers the fundamentals and applications of sintering based processes in ceramic engineering. It includes solid-state, liquid phase, reactive and vapor phase sintering and covers densifying and non-densifying mechanisms as well as microstructure development for bulk, coatings, and additively manufactured parts. The course covers technologies used in the processing of ceramics. Prerequisite: MTGN310, MTGN352, MTGN281. Co-requisite: MTGN345.
Course Learning Outcomes

- 1. exhibit a basic understanding of sintering mechanisms in ceramics
- 2. engineer microstructure development of powder-based specimens from green body to dense polycrystalline ceramics
- 3. design a thermal profile to produce a desired microstructure for a given material for different processing techniques
- 4. to characterize abnormal grain growth, solute drag, pore drag, and Zener pinning

MTGN348. MICROSTRUCTURAL DEVELOPMENT. 3.0 Semester Hrs.
An introduction to the relationships between microstructure and properties of materials, with emphasis on metallic and ceramic systems; Fundamentals of imperfections in crystalline materials on material behavior; recrystallization and grain growth; strengthening mechanisms: microstructural refinement, solid solution strengthening, precipitation strengthening, cold work; and phase transformations. Prerequisite: MTGN211, MTGN251. Co-requisite: MTGN281, MTGN348L.
Course Learning Outcomes

- ABET 1, 3

MTGN348L. MICROSTRUCTURAL DEVELOPMENT LABORATORY. 1.0 Semester Hr.
Experiments in microstructural development of materials to supplement the lectures of MTGN348. 3 hours lab; 1 semester hour. Co-requisite: MTGN348.
Course Learning Outcomes

- ABET 1, 3

MTGN350. STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS. 3.0 Semester Hrs.
Introduction to statistical process control, process capability analysis and experimental design techniques. Statistical process control theory and techniques developed and applied to control charts for variables and attributes involved in process control and evaluation. Process capability concepts developed and applied to the evaluation of manufacturing processes. Theory of designed experiments developed and applied to full factorial experiments, fractional factorial experiments, and multilevel experiments. Analysis of designed experiments by graphical and statistical techniques. Introduction to computer software for statistical process control and for the design and analysis of experiments.

Course Learning Outcomes

- ABET 1, 3

MTGN352. METALLURGICAL AND MATERIALS KINETICS. 3.0 Semester Hrs.
Introduction to reaction kinetics: chemical kinetics, atomic and molecular diffusion, surface thermodynamics and kinetics of interfaces and nucleation-and-growth. Applications to materials processing and performance aspects associated with gas/solid reactions, precipitation and dissolution behavior, oxidation and corrosion, purification of semiconductors, carburizing of steel, formation of p-n junctions and other important materials systems. Prerequisite: MTGN272. Co-requisite: MTGN251.
Course Learning Outcomes

- ABET 1, 2

MTGN398. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN399. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN403. SENIOR THESIS. 3.0 Semester Hrs.
(I, II,S) Two-semester individual research under the direction of members of the MME faculty. Work may include library and laboratory research on topics of relevance. Oral presentation will be given at the end of the second semester and written thesis submitted to committee of evaluation. 3 hours research; 3 semester hours.
Course Learning Outcomes

- depends

MTGN410. THERMAL PROPERTIES OF CERAMICS. 3.0 Semester Hrs.
This course covers the fundamentals and applications of ceramic materials? responses to thermal energy. Thermal responses are fundamentally borne from atomic scale processes which will be covered in detail. Particular attention is paid to thermal conduction, melting, thermally induced strain, thermomechanical stresses, and engineering microstructures to obtain specific thermal performances. Prerequisite: MTGN315, MTGN310.
Course Learning Outcomes

- 1. Understand atomic and thermodynamic material responses to thermal energy
- 2. Understand and engineer thermal conduction processes in materials and devices
- 3. Engineer thermomechanical responses to thermal energy including expansion and thermal shock
- 4. Engineer ceramic materials for thermal insulation applications

MTGN414. ADVANCED PROCESSING AND SINTERING OF CERAMICS. 3.0 Semester Hrs.
Principles of ceramics processing and the relationship between processing and microstructure, with a focus on advanced microstructural control using thermal and athermal energy input in single and multiphase systems. Principles will be illustrated using case studies on specific ceramic materials. A project to design a ceramic fabrication process is required. Prerequisite: MTGN314. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- ABET 1, 2, 3

MTGN419. NON-CRYSTALLINE MATERIALS. 3.0 Semester Hrs.
Introduction to the principles of glass science and engineering and non-crystalline materials in general. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisite: MTGN211 and MTGN314.
Course Learning Outcomes

- ABET 1, 2

MTGN429. METALLURGICAL ENVIRONMENT. 3.0 Semester Hrs.
(I) Examination of the interface between metallurgical process engineering and environmental engineering. Wastes, effluents and their point sources in metallurgical processes such as mineral concentration, value extraction and process metallurgy are studied in context. Fundamentals of metallurgical unit operations and unit processes with those applicable to waste and effluent control, disposal and materials recycling are covered. Engineering design and engineering cost components are also included for selected examples. Fundamentals and applications receive equal coverage. Prerequisites: MTGN334. 3 hours lecture; 3 semester hours.

MTGN430. PHYSICAL CHEMISTRY OF IRON AND STEELMAKING. 3.0 Semester Hrs.
Physical chemistry principles of blast furnace and direct reduction production of iron and refining of iron to steel. Discussion of raw materials, productivity, impurity removal, deoxidation, alloy additions, and ladle metallurgy. Prerequisite: MTGN334, MTGN251.
Course Learning Outcomes

- ABET 1, 2

MTGN431. HYDRO- AND ELECTRO-METALLURGY. 3.0 Semester Hrs.
Physicochemical principles associated with the extraction and refining of metals by hydro- and electrometallurgical techniques. Discussion of unit processes in hydrometallurgy, electrowinning, and electrorefining. Analysis of integrated flowsheets for the recovery of nonferrous metals. Offered every other year. 3 hours lecture; 3 semester hours. Prerequisite: MTGN334, MTGN352, and MTGN251. Co-requisite: MTGN461.
Course Learning Outcomes

- ABET 1

MTGN432. PYROMETALLURGY. 3.0 Semester Hrs.
Extraction and refining of metals including emerging practices. Modifications driven by environmental regulations and by energy minimization. Analysis and design of processes and the impact of economic constraints. Prerequisite: MTGN334. 3 hours lecture; 3 semester hours.

MTGN442. ENGINEERING ALLOYS. 3.0 Semester Hrs.
This course is intended to be an important component of the physical metallurgy sequence, to reinforce and integrate principles from earlier courses, and enhance the breadth and depth of understanding of concepts in a wide variety of alloy systems. Metallic systems considered include iron and steels, copper, aluminum, titanium, superalloys, etc. Phase stability, microstructural evolution and structure/property relationships are emphasized. Offered every year. Prerequisite: MTGN348.
Course Learning Outcomes

- ABET 2, 6

MTGN445. MECHANICAL PROPERTIES OF MATERIALS. 3.0 Semester Hrs.
Mechanical properties and relationships. Plastic deformation of crystalline materials. Relationships of microstructures to mechanical strength. Fracture, creep, and fatigue. 3 hours lecture, 3 semester hours. Prerequisite: MTGN348 and CEEN241 and CEEN311. Co-requisite: MTGN445L.
Course Learning Outcomes

- ABET 4, 5,7

MTGN445L. MECHANICAL PROPERTIES OF MATERIALS LABORATORY. 1.0 Semester Hr.
Laboratory sessions devoted to advanced mechanical-testing techniques to illustrate the application of the fundamentals presented in the lectures of MTGN445. Corequisite: MTGN445. 3 hours lab; 1 semester hour.
Course Learning Outcomes

- ABET 4,5 7

MTGN451. CORROSION ENGINEERING. 3.0 Semester Hrs.
Principles of electrochemistry. Corrosion mechanisms. Methods of corrosion control including cathodic and anodic protection and coatings. Examples of corrosion problems and solutions from various industries. Prerequisite: MTGN251.
Course Learning Outcomes

- No change

MTGN456. ELECTRON MICROSCOPY. 2.0 Semester Hrs.
Introduction to electron optics and the design and application of transmission and scanning electron microscopes. Interpretation of images produced by various contrast mechanisms. Electron diffraction analysis and the indexing of electron diffraction patterns. 2 hours lecture; 2 semester hours. Prerequisite: MTGN211. Co-requisite: MTGN456L.
Course Learning Outcomes

- ABET 1, 3

MTGN456L. ELECTRON MICROSCOPY LABORATORY. 1.0 Semester Hr.
Equivalent with MTGN458,
Laboratory exercises to illustrate specimen preparation techniques, microscope operation, and the interpretation of images produced from a variety of specimens, and to supplement the lectures in MTGN456. 3 hours lab; 1 semester hour. Co-requisite: MTGN456.
Course Learning Outcomes

- ABET 1, 3

MTGN457. SOLIDIFICATION. 3.0 Semester Hrs.
This course is intended to provide students with a working understanding of solidification processing of metals relevant to crystal growth, casting, welding, and additive manufacturing. Topics in the course are: 1) thermodynamics, 2) nucleation, 3) heat transfer, 4) interface stability and solidification morphology, 5) dendritic growth, 6) microsegregation, and 7) columnar vs equiaxed dendritic growth. Prerequisite: MTGN348.
Course Learning Outcomes

MTGN461. TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS. 3.0 Semester Hrs.
Introduction to the conserved-quantities: momentum, heat, and mass transfer, and application of chemical kinetics to elementary reactor-design. Examples from materials processing and process metallurgy. Molecular transport properties: viscosity, thermal conductivity, and mass diffusivity of materials encountered during processing operations. Uni-directional transport: problem formulation based on the required balance of the conserved- quantity applied to a control-volume. Prediction of velocity, temperature and concentration profiles. Equations of change: continuity, motion, and energy. Transport with two independent variables (unsteady-state behavior). Interphase transport: dimensionless correlations friction factor, heat, and mass transfer coefficients. Elementary concepts of radiation heat-transfer. Flow behavior in packed beds. Design equations for: continuous- flow/batch reactors with uniform dispersion and plug flow reactors. Digital computer methods for the design of metallurgical systems. Prerequisite: MATH225, MTGN334, and MTGN352. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- ABET 1,3

MTGN462. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.
This course will examine, using case studies, how industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisites: CEEN301, CEEN302, and CHGN403. 3 hours lecture; 3 semester hours.

MTGN464. FORGING AND FORMING. 2.0 Semester Hrs.
Introduction to plasticity, survey and analysis of working operations including forging, extrusion, rolling, wire drawing and sheet-metal forming. Metallurgical structure evolution during working. Prerequisite: MTGN281 or CEEN311, MTGN348. Co-requisite: MTGN464L.
Course Learning Outcomes

- ABET 1

MTGN464L. FORGING AND FORMING LABORATORY. 1.0 Semester Hr.
Experiments in forging and forming to supplement the lectures of MTGN464. 3 hours lab; 1 semester hour. Co-requisite: MTGN464.
Course Learning Outcomes

- ABET 1

MTGN465. MECHANICAL PROPERTIES OF CERAMICS. 3.0 Semester Hrs.
Mechanical properties of ceramics and ceramic-based composites; brittle fracture of solids; toughening mechanisms in composites; fatigue, high-temperature mechanical behavior, including fracture and creep deformation. Offered every year. Prerequisite: MTGN310, CEEN241, CEEN311. Co-requisite: MTGN465L.

Course Learning Outcomes

- ABET 1

MTGN465L. MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES LABORATORY. 1.0 Semester Hr.
Mechanical properties of ceramics and ceramic-based composites; brittle fracture of solids; toughening mechanisms in composites; fatigue, high temperature mechanical behavior, including fracture, creep deformation. Prerequisite: MTGN345. Co-requisite: MTGN465.
Course Learning Outcomes

- 1) Reduce, interpret and analyze experimental data from a variety of mechanical property tests.
- 2) Prepare and submit concise and coherent technical laboratory reports.
- 3) apply mechanical property models such as fracture mechanics to ceramic and composite behavior.
- 4) Describe ceramic and composite mechanical properties and behavior in terms of mechanisms.
- 5) Identify and classify different types of ceramic and composite mechanical constitutive responses.

MTGN467. MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION. 2.0 Semester Hrs.
Application of fundamental materials engineering principles to the design of systems, processes, and/or components for extraction, synthesis, operation and/or selection of materials in open-ended projects with realistic constraints. Project topics range from processes used for metallurgical processing and extraction to design and development of emergent materials to process/component analysis and (re)design. Chemical and microstructural characterization and property measurements provide the basis for linking synthesis to application and/or process to product. Selection criteria tied to specific requirements drive design under realistic constraints that include an appropriate mix of technical, economic, safety, and other considerations. Activities are carried out in teams in collaboration with project sponsors/clients. 1 hour lecture, 3 hours lab; 2 semester hours. Prerequisite: MTGN350, MTGN352, and MTGN348 or MTGN345.
Course Learning Outcomes

- ABET 1-7

MTGN468. MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION. 2.0 Semester Hrs.
Application of fundamental materials engineering principles to the design of systems, processes, and/or components for extraction, synthesis, operation and/or selection of materials in open-ended projects with realistic constraints. Project topics range from processes used for metallurgical processing and extraction to design and development of emergent materials to process/component analysis and (re)design. Chemical and microstructural characterization and property measurements provide the basis for linking synthesis to application and/or process to product. Selection criteria tied to specific requirements drive design under realistic constraints that include an appropriate mix of technical, economic, safety, and other considerations. Activities are carried out in teams in collaboration with project sponsors/clients. Prerequisite: MTGN467. 1 hour lecture, 3 hours lab; 2 semester hours.
Course Learning Outcomes

- ABET 1-7

MTGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Fuel cells provide one of the most efficient means for converting the chemical energy stored in a fuel to electrical energy. Fuel cells offer improved energy efficiency and reduced pollution compared to heat engines. While composed of no (or very few) moving parts, a complete fuel cell system amounts to a small chemical plant for the production of power. This course introduces students to the fundamental aspects of fuel cell systems, with emphasis placed on proton exchange membrane (PEM) and solid oxide fuel cells (SOFC). Students will learn the basic principles of electrochemical energy conversion while being exposed to relevant topics in materials science, thermodynamics, and fluid mechanics. Offered every other year. Prerequisite: PHGN200, MATH225, MTGN251 or CHGN209 or CHGN210 or MEGN261.
Course Learning Outcomes

- ABET 1, 2, 6

MTGN472. BIOMATERIALS I. 3.0 Semester Hrs.
This course introduces biomaterials by combining materials engineering principles with understanding of aspects of molecular and cellular biology so that students learn how materials interact with biological systems, particularly for medical use. The course is organized around four main topics: 1) fundamental properties of biomaterials; 2) fundamental concepts in biology relevant to biomaterials; 3) interactions of physiological systems with biomaterials, and 4) processing of biopolymers, bioceramics and glasses, biometals and composites. Key topics covered include processing of materials to achieve specific biological responses, surface energy and surface modification; protein adsorption; cell adhesion, spreading and migration; biomaterials implantation and acute inflammation; blood-materials interactions; biofilms and biomaterials degradation; and clinical applications of biomaterials. Offered every other year. Prerequisite: MTGN202. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- ABET 1, 5, 6

MTGN473. COMPUTATIONAL MATERIALS. 3.0 Semester Hrs.
(II) Computational Materials is a course designed as an introduction to computational approaches used in modern materials science and engineering, and to provide the hands-on experience in using massively parallel supercomputers and executing popular materials software packages. The main goal is to provide exposure to students to the growing and highly interdisciplinary field of computational materials science and engineering, through a combination of lectures, hands-on exercises and a series of specifically designed projects. The course is organized to cover different length scales including: atomistic (electronic structure) calculations, molecular dynamics, and phase equilibria modeling. The emerging trends in data driven materials discovery and design are also covered. Particular emphasis is placed on the validation of computational results and recent trends in integrating theory, computations and experiment. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Module 1: 1. Introduction to computational materials science and engineering
- Module 2: Electronic structure calculations
- Module 3: Molecular dynamics calculations
- Module 4: Materials thermodynamics and phase equilibria modeling

MTGN475. METALLURGY OF WELDING. 2.0 Semester Hrs.
Introduction to welding processes; thermal aspects; selection of filler metals; stresses; stress relief and annealing; pre- and postweld heat treating; weld defects; welding ferrous and nonferrous alloys; weld metal phase transformations; metallurgical evaluation of resulting weld microstructures and properties; and welding tests. Offered every year. Prerequisite: MTGN348. Co-requisite: MTGN475L.
Course Learning Outcomes

- ABET 1, 3, 4

MTGN475L. METALLURGY OF WELDING LABORATORY. 1.0 Semester Hr.
Equivalent with MTGN477,
Experiments designed to supplement the lectures in MTGN475. Offered every year. Co-requisite: MTGN475.
Course Learning Outcomes

- ABET 1,3, 4

MTGN480. ADVANCED WELDING METALLURGY. 3.0 Semester Hrs.
This course will explore microstructural development that occurs during welding. Solidification in the fusion zone as well as solid-state microstructural changes in the heat affected zone will be discussed. We will use the understanding of microstructural changes during welding to interpret cracking mechanisms and unique behaviors of specific alloy systems. The interrelationship between modeling/simulation and experiments will be emphasized. Throughout the course, we will think about how the people to who actually weld (welders) can provide critical insight to solve welding metallurgy problems. Prerequisite: MTGN348. Co-requisite: none.
Course Learning Outcomes

- At the completion of the course, the student will be able to: 1) Describe welding related phenomena with correct terminology 2) Understand how composition affects welding behavior 3) Apply models to predict aspects of microstructure, properties, and performance 4) Evaluate model predictions against experimental results

MTGN497. SUMMER PROGRAMS. 0.0 Semester Hrs.
(S) Summer registration. Repeatable.

MTGN498. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II, S) Independent advanced-work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Selection of problem is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit to a maximum of 6 hours.

MTGN501. MME GRADUATE SEMINAR. 0.5 Semester Hrs.
(I, II) All full-time MME graduate students must attend the Metallurgical and Materials Engineering seminar. Students must take the Graduate Seminar course every semester that they are enrolled at CSM. At the end of each semester, students are assigned either a satisfactory or unsatisfactory progress grade, based on attendance, until the final semester of the student's degree program, when a letter grade is assigned based on all prior semesters' attendance grades. As a result, while these courses are taken each year, only a maximum of 1.0 hours total of course credit is conferred. Students who have official part-time status are not required to sign up for Graduate Seminar. Attendance of other seminars outside MME can substitute for seminar attendance in MME following course instructor approval. 1 hour lecture; 0.5 hours. Repeatable up to 1 hour.
Course Learning Outcomes

- Students will develop an appreciation for the diversity of research and research methods in materials science and engineering.

MTGN510. THERMAL PROPERTIES OF CERAMICS. 3.0 Semester Hrs.
This course covers the fundamentals and applications of ceramic materials' responses to thermal energy. Thermal responses are fundamentally borne from atomic scale processes which will be covered in detail. Particular attention is paid to thermal conduction, melting, thermally induced strain, thermomechanical stresses, and engineering microstructures to obtain specific thermal performances. Prerequisite: MTGN315, MTGN310.
Course Learning Outcomes

- Same as existing MTGN410 course syllabus.

MTGN511. SPECIAL METALLURGICAL AND MATERIALS ENGINEERING PROBLEMS. 1-3 Semester Hr.
(I) Independent advanced work, not leading to a thesis. This may take the form of conferences, library, and laboratory work. Selection of assignment is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN512. SPECIAL METALLURGICAL AND MATERIALS ENGINEERING PROBLEMS. 1-3 Semester Hr.
(II) Continuation of MTGN511. Prerequisite: Selection of topic. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN523. APPLIED SURFACE AND SOLUTION CHEMISTRY. 3.0 Semester Hrs.
(II) Solution and surface chemistry of importance in mineral and metallurgical operations. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN526. GEL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
An introduction to the science and technology of particulate and polymeric gels, emphasizing inorganic systems. Interparticle forces. Aggregation, network formation, percolation, and the gel transition. Gel structure, rheology, and mechanical properties. Application to solid-liquid separation operations (filtration, centrifugation, sedimentation) and to ceramics processing. Prerequisite: Graduate Status. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN527. 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. 3 hours lecture; 3 semester hours.

MTGN528. 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. Prerequisites: Graduate or Senior in good-standing. 3 hours lecture, 3 semester hours.

MTGN529. METALLURGICAL ENVIRONMENT. 3.0 Semester Hrs.
(I) Effluents, wastes, and their point sources associated with metallurgical processes, such as mineral concentration and values extraction? providing for an interface between metallurgical process engineering and the environmental engineering areas. Fundamentals of metallurgical unit operations and unit processes, applied to waste and effluents control, recycling, and waste disposal. Examples which incorporate engineering design and cost components are included. Prerequisites: MTGN334. 3 hours lecture; 3 semester hours.

MTGN530. ADVANCED IRON AND STEELMAKING. 3.0 Semester Hrs.
(I) 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. Prerequisite: DCGN209 or MTGN351. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MTGN531. THERMODYNAMICS OF METALLURGICAL AND MATERIALS PROCESSING. 3.0 Semester Hrs.
(I) 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. 3 hours lecture; 3 semester hours.

MTGN532. 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. Prerequisites: Graduate or Senior in good- standing. 3 hours lecture, 3 semester hours.

MTGN533. 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. 3 hours lecture, 3 semester hours.

MTGN535. PYROMETALLURGICAL PROCESSES. 3.0 Semester Hrs.
(II) 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. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN536. OPTIMIZATION AND CONTROL OF METALLURGICAL SYSTEMS. 3.0 Semester Hrs.
Application of modern optimization and control theory to the analysis of specific systems in extractive metallurgy and mineral processing. Mathematical modeling, linear control analysis, dynamic response, and indirect optimum seeking techniques applied to the process analysis of grinding, screening, filtration, leaching, precipitation of metals from solution, and blast furnace reduction of metals. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN537. ELECTROMETALLURGY. 3.0 Semester Hrs.
(II) 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. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of even years only.).

MTGN538. HYDROMETALLURGY. 3.0 Semester Hrs.
(II) 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. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN539. PRINCIPLES OF MATERIALS PROCESSING REACTOR DESIGN. 3.0 Semester Hrs.
(II) 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. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN545. FATIGUE AND FRACTURE. 3.0 Semester Hrs.
(I) Basic fracture mechanics as applied to engineering materials, S-N curves, the Goodman diagram, stress concentrations, residual stress effects, effect of material properties on mechanisms of crack propagation. Prerequisite: none. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN545L. MECHANICAL PROPERTIES OF MATERIALS LABORATORY. 3.0 Semester Hrs.
Laboratory sessions devoted to advanced mechanical-testing techniques to illustrate the application of the fundamentals presented in the lectures of MTGN445. 3 hours lab; 1 semester hour. Co-requisite: MTGN598H.
Course Learning Outcomes

- Same as existing MTGN445L

MTGN548. TRANSFORMATIONS IN METALS. 3.0 Semester Hrs.
(I) Surface and interfacial phenomena, order of transformation, grain growth, recovery, recrystallization, solidification, phase transformation in solids, precipitation hardening, spinoidal decomposition, martensitic transformation, gas metal reactions. Prerequisite: none. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN549. CURRENT DEVELOPMENTS IN FERROUS ALLOYS. 3.0 Semester Hrs.
(I) Development and review of solid state transformations and strengthening mechanisms in ferrous alloys. Application of these

principles to the development of new alloys and processes such as high strength low alloy steels, high temperature alloys, maraging steels, and case hardening processes. Prerequisite: MTGN348. 3 hours lecture; 3 semester hours.

MTGN551. ADVANCED CORROSION ENGINEERING. 3.0 Semester Hrs.
(I) Advanced topics in corrosion engineering. Case studies and industrial application. Special forms of corrosion. Advanced measurement techniques. Prerequisite: MTGN451. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MTGN553. STRENGTHENING MECHANISMS. 3.0 Semester Hrs.
(II) Strain hardening in polycrystalline materials, dislocation inter actions, effect of grain boundaries on strength, solid solution hardening, martensitic transformations, precipitation hardening, point defects. Prerequisite: MTGN543 or concurrent enrollment. 3 hours lecture;3 semester hours. (Spring of even years only.).

MTGN555. SOLID STATE THERMODYNAMICS. 3.0 Semester Hrs.
(I) Thermodynamics applied to solid state reactions, binary and ternary phase diagrams, point, line and planar defects, interfaces, and electrochemical concepts. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN556. TRANSPORT IN SOLIDS. 3.0 Semester Hrs.
(I) Thermal and electrical conductivity. Solid state diffusion in metals and metal systems. Kinetics of metallurgical reactions in the solid state. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of even years only.).

MTGN556L. ELECTRON MICROSCOPY LABORATORY. 3.0 Semester Hrs.
Laboratory exercises to illustrate specimen preparation techniques, microscope operation, and the interpretation of images produced from a variety of specimens, and to supplement the lectures in MTGN456. 3 hours lab; 1 semester hour. Co-requisite: MTGN598I.
Course Learning Outcomes

- Same as existing MTGN456L outcomes.

MTGN557. SOLIDIFICATION. 3.0 Semester Hrs.
(I) Heat flow and fluid flow in solidification, thermodynamics of solidification, nucleation and interface kinetics, grain refining, crystal and grain growth, constitutional supercooling, eutectic growth, solidification of castings and ingots, segregation, and porosity. Prerequisite: none. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN560. ANALYSIS OF METALLURGICAL FAILURES. 3.0 Semester Hrs.
(II) Applications of the principles of physical and mechanical metallurgy to the analysis of metallurgical failures. Nondestructive testing. Fractography. Case study analysis. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN564. ADVANCED FORGING AND FORMING. 3.0 Semester Hrs.
(II) Overview of plasticity. Examination and Analysis of working operations of forging, extrusion, rolling, wire drawing and sheet metal forming. Metallurgical structure evolution during working. Laboratory experiments involving metal forming processes. Prerequisites: MTGN445/MLGN505, 2 hours lecture; 3 hours lab, 3 semester hours.

MTGN565. MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES. 3.0 Semester Hrs.
(I) Mechanical properties of ceramics and ceramic-based composites; brittle fracture of solids; toughening mechanisms in composites; fatigue, high temperature mechanical behavior, including fracture, creep deformation. Prerequisites: MTGN445 or MLGN505. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MTGN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN569,MEGN569,MLGN569,
(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. 3 credit hours.

MTGN570. BIOCOMPATIBILITY OF MATERIALS. 3.0 Semester Hrs.
Introduction to the diversity of biomaterials and applications through examination of the physiologic environment in conjunction with compositional and structural requirements of tissues and organs. Appropriate domains and applications of metals, ceramics and polymers, including implants, sensors, drug delivery, laboratory automation, and tissue engineering are presented. Prerequisites: BIOL110 or equivalent. 3 hours lecture; 3 semester hours.

MTGN572. BIOMATERIALS. 3.0 Semester Hrs.
Equivalent with MLGN572,
A broad overview on materials science and engineering principles for biomedical applications with three main topics: 1) The fundamental properties of biomaterials; 2) The fundamental concepts in biology; 3) The interactions between biological systems with exogenous materials. Examples including surface energy and surface modification; protein adsorption; cell adhesion, spreading and migration; biomaterials implantation and acute inflammation; blood-materials interactions and thrombosis; biofilm and biomaterials-related pathological reactions. Basic principles of bio-mimetic materials synthesis and assembly will also be introduced. 3 hours lecture; 3 semester hours.

MTGN573. COMPUTATIONAL MATERIALS. 3.0 Semester Hrs.
(II) Computational Materials is a course designed as an introduction to computational approaches and codes used in modern materials science and engineering, and to provide the hands?on experience in using massively parallel supercomputers and popular materials software packages. The main goal is to provide exposure to students to the growing and highly interdisciplinary field of computational materials science and engineering, through a combination of lectures, hands-on exercises and a series of specifically designed projects. The course is organized to cover different length scales including: atomistic (electronic structure) calculations, molecular dynamics, and phase equilibria modeling. The emerging trends in data driven materials discovery and design are also covered. Particular emphasis is placed on the validation of computational results and recent trends in integrating theory, computations and experiment. Graduate students are expected to successfully complete 4 projects while the undergraduate students are required to finish 3 out of 4 projects. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Module 1: 1. Introduction to computational materials science and engineering
- Module 2: Electronic structure calculations
- Module 3: Molecular dynamics calculations
- Module 4: Materials thermodynamics and phase equilibria modeling

MTGN580. ADVANCED WELDING METALLURGY. 3.0 Semester Hrs.
(II) Weldability of high strength steels, high alloys, and light metals; Welding defects; Phase transformations in weldments; Thermal experience in weldments; Pre- and Post-weld heat treatment; Heat

affected zone formation, microstructure, and properties; Consumables development. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN593. NUCLEAR MATERIALS SCIENCE AND ENGINEERING. 3.0 Semester Hrs.
(I) Introduction to the physical metallurgy of nuclear materials, including the nuclear, physical, thermal, and mechanical properties for nuclear materials, the physical and mechanical processing of nuclear alloys, the effect of nuclear and thermal environments on structural reactor materials and the selection of nuclear and reactor structural materials are described. Selected topics include ceramic science of ceramic nuclear material, ceramic processing of ceramic fuel, nuclear reaction with structural materials, radiation interactions with materials, the aging of nuclear materials, cladding, corrosion and the manufacturing of fuels elements. Relevant issues in the modern fuel cycle will also be introduced including nuclear safety, reactor decommissioning, and environmental impacts. Prerequisites: Graduate or Senior in good-standing. 3 hours lecture, 3 semester hours. (Fall of even years only.).

MTGN598. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MTGN598. MECHANICAL PROPERTIES OF MATERIALS. 3.0 Semester Hrs.
Mechanical properties and relationships. Plastic deformation of crystalline materials. Relationships of microstructures to mechanical strength. Fracture, creep, and fatigue. 3 hours lecture, 3 semester hours. Prerequisite: MTGN348 and CEEN241 and CEEN311. Co-requisite: MTGN598HL.
Course Learning Outcomes

- No changes to current class outcomes

MTGN598. ELECTRON MICROSCOPY. 2.0 Semester Hrs.
Introduction to electron optics and the design and application of transmission and scanning electron microscopes. Interpretation of images produced by various contrast mechanisms. Electron diffraction analysis and the indexing of electron diffraction patterns. 2 hours lecture; 2 semester hours. Prerequisite: MTGN211. Co-requisite: MTGN556L.
Course Learning Outcomes

- No changes to current class outcomes

MTGN599. 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.

MTGN605. ADVANCED TRANSMISSION ELECTRON MICROSCOPY. 2.0 Semester Hrs.
Introduction to transmission electron microscopy techniques and their application to materials characterization. Topics include electron optics, electron-specimen interactions, imaging, diffraction, contrast mechanisms, defect analyses, compositional measurements using energy dispersive x-ray spectroscopy and energy loss spectroscopy, scanning transmission electron microscopy, high angle annular dark field imaging, energy filtered TEM and high resolution phase contrast imaging. Prerequisite: MTGN 505. Co-requisite; MTGN 605L. 2 hours lecture, 2 semester hours.

MTGN605L. ADVANCED TRANSMISSION ELECTRON MICROSCOPY LABORATORY. 1.0 Semester Hr.
Specimen preparation techniques and their application to materials characterization. Topics include electron optics, electron-specimen interactions, imaging, diffraction, contrast mechanisms, defect analyses, compositional measurements using energy dispersive x-ray spectroscopy and energy loss spectroscopy, scanning transmission electron microscopy, high angle annular dark field imaging, energy filtered TEM and high resolution phase contrast imaging. Prerequisite: Concurrent enrollment in MTGN 605. 3 hours lab, 1 semester hour.

MTGN631. 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. Prerequisite: MATH225 and MTGN461 or equivalent. 3 hours lecture; 3 semester hours.

MTGN656. ADVANCED ELECTRON MICROSCOPY. 2.0 Semester Hrs.
Advanced introduction to electron optics and the design and application of transmission and scanning electron microscopes. Interpretation of images produced by various contrast mechanisms. Electron diffraction analysis and the indexing of electron diffraction patterns. Co-requisite: MTGN656L.
Course Learning Outcomes

MTGN656L. ADVANCED ELECTRON MICROSCOPY LABORATORY. 1.0 Semester Hr.
Laboratory exercises to illustrate specimen preparation techniques, microscope operation, and the interpretation of images produced from a variety of specimens, and to supplement the lectures in MTGN456. Co-requisite: MTGN656.
Course Learning Outcomes

MTGN698. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MTGN699. 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.

MTGN700. GRADUATE RESEARCH CREDIT: MASTER OF ENGINEERING. 1-6 Semester Hr.
(I, II, S) Research credit hours required for completion of the degree Master of Engineering. Research under the direct supervision of a faculty advisor. Credit is not transferable to any 400, 500, or 600 level courses. However, MTGN 705 credit hours may be transferred, in accordance with the requirements for this (M.E.) degree, by a Master of Science graduate-student who previously accumulated these credit-hours and

subsequently opted to change their degree program to a Master of Engineering. Repeatable for credit. Variable: 1 to 6 semester hours.

MTGN707. 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.