METALLURGICAL ENGINEERING

Metallurgical engineering is one of two B.S. degrees offered by the materials science and engineering department. Metallurgical engineering is a broad discipline that studies metals production and recycling, the manufacturing of components from metals and alloys, the processing and treatment of metals to achieve improved properties, and the design of metallic materials for specific applications. Missouri S&T has one of the largest and most comprehensive metallurgical engineering programs in the United States. It is the only such program in Missouri or in any of the surrounding states.

The field of metallurgical engineering starts with the production and recycling of metals such as aluminum, steel, copper, magnesium and titanium. Once these metals are made, metallurgical engineers design forming and processing techniques to transform these metals into useful shapes with the properties required for their application. For example, light-weight magnesium is cast to make cell phones, zinc-coated steel is stamped to make corrosion resistant auto bodies, aluminum is formed to make the strong but lightweight wings of jet aircraft, tungsten powder is consolidated and drawn into filaments for incandescent light bulbs, and steel I-beams are hot-rolled for the construction of skyscrapers. Metallurgical engineers control the properties of metallic materials by altering the microscopic structure with alloying additions and special treatments. This approach leads to products such as corrosion-resistant stainless steels, ultra-lightweight alloys for aircraft, wear-resistant alloys for engines, and shape-memory alloys for space structures. In addition, investigating material failures and monitoring service life are tasks that are performed by metallurgists.

Although all metallurgical engineering students take the same basic required courses in metallurgical engineering, students can select several technical electives to emphasize their particular area of interest. Students are also encouraged to undertake summer and cooperative training employment to supplement both their academic studies and incomes.

The department is housed in McNutt Hall and has outstanding facilities for both classroom and laboratory learning. There are several optical and electron microscopes, a well equipped metals casting and joining laboratory, and comprehensive metal testing facilities. The department continuously upgrades its facilities for classroom and laboratory learning. The department has also enhanced its computer applications laboratory with the addition of new software and computers, and improved network access. Additional information is available at http://mse.mst.edu/.

Mission Statement

The mission of the program is to provide a quality, comprehensive undergraduate and graduate education in the traditional areas of metallurgical engineering. The major program goal is to produce a bachelor of science graduate with a sound fundamental knowledge and extensive hands-on technical, communication, and leadership skills, capable of contributing in any technical area associated with metallurgy. The program is also committed to a strong graduate program, which ensures significant research activity, an active and involved faculty, and a robust, healthy environment for education. The provision of service course work for students in other engineering disciplines is also an important goal, as is interaction with professional societies and industry to promote continuing education, research, and technical information transfer. The utilization of the departmental resources to assist the state agencies and industry of Missouri and the mid-west is an integral part of the departmental mission.

The program educational objectives of the metallurgical engineering program:

- Our graduates will be leaders in the science, technology, and management of metallurgical engineering
- Our graduates will serve their profession and society
- Our graduates will continually enhance their professional skills and educational background

The specific outcomes of the metallurgical engineering program are:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Bachelor of Science Metallurgical Engineering

Entering freshmen desiring to study metallurgical engineering will be admitted to the Foundational Engineering and Computing Program. They will be permitted to state a metallurgical engineering preference, which will be used as a consideration for available freshman departmental scholarships. The focus of the Foundational Engineering and Computing Program is on enhanced advising and career counseling, with the goal of providing to the student the information necessary to make an informed decision regarding the choice of a major.

For the bachelor of science degree in metallurgical engineering a minimum of 128 credit hours is required. These requirements are in addition to credit received for algebra, trigonometry, and basic ROTC courses. A student must maintain an average of at least two grade points per credit hour in metallurgical engineering.

The metallurgical engineering curriculum contains a required number of hours in humanities and social sciences as specified by the Engineering Accreditation Commission of ABET. Each student's program of study must contain a minimum of 18 credit hours of course work from

the humanities and the social sciences areas and should be chosen according to the following rules:

1. All students are required to take one American history course and one economics course. The history course is to be selected from HISTORY 1200, HISTORY 1300, HISTORY 1310, or POL SCI 1200. The economics course may be either ECON 1100 or ECON 1200.
2. Of the remaining hours, six credit hours must be taken in humanities or social sciences from the approved list of humanities and social science (HSS) courses. Students may receive humanities credit for foreign language courses in their native tongue only if the course is at the 4000 level.)
3. Special topics, special problems courses and honors seminars are allowed only by petition to and approval by the student's department chair.

Freshman Year

First Semester	Credits	Second Semester	Credits
FR ENG 1100	1	CHEM 1320	3
CHEM 1310	4	MATH 1215	4
CHEM 1319	1	PHYSICS 1135	4
MATH 1214	4	Hum/Soc Sci Elective[1]	3
ENGLISH 1120	3	MECH ENG 1720	3
Hum/Soc Sci Elective[1]	3		
	16		17

Sophomore Year

First Semester	Credits	Second Semester	Credits
PHYSICS 2135	4	CER ENG 3230	3
MATH 2222	4	CIV ENG 2210	3
MET ENG 2110	3	MET ENG 2125	2
CIV ENG 2200	3	MET ENG 3130	3
Hum/Soc Sci Elective[1]	3	MET ENG 3420	3
		MET ENG 3425	1
	17		15

Junior Year

First Semester	Credits	Second Semester	Credits
MET ENG 3320	3	MET ENG 3225	1
MATH 3304[2]	3	MET ENG 3220	3
MET ENG 3120	3	CER ENG 3410	3
MET ENG 3125	2	Core Elective [4]	3
MET ENG 4420	3	Out of Department Technical Elective[3]	3
Communication Elective[1]	3	Hum/Soc Sci Elective[1]	3
	17		16

Senior Year

First Semester	Credits	Second Semester	Credits
MET ENG 4096	3	MET ENG 4097	3
Statistics Course[2]	3	Hum/Soc Sci Elective[1]	3
MET ENG 4350	3	Technical Elective[5]	3
Core Elective [4]	3	Free Elective[6]	3
Technical Elective[5]	3	Core Elective[4]	3
	15		15

Total Credits: 128

1 Eighteen hours of required H/SS electives of which three hours must be history (HISTORY 1200, HISTORY 1300, HISTORY 1310, or POL SCI 1200), three hours of economics (ECON 1100 or ECON 1200) and three hours communications (ENGLISH 1160, ENGLISH 3560, or SP&M S 1185)

2 All metallurgical engineering students must take MATH 3304 and one statistics course (STAT 3113 or STAT 3115)

3 CHEM ENG 5320, CHEM 2210 or CHEM 2310 or CHEM 3410 or CHEM 4810, ELEC ENG 2100 & ELEC ENG 2101 or ELEC ENG 2800, GEOLOGY 2610, MATH 5603 or MATH 5325, MECH ENG 5212 or MECH ENG 5220 or MECH ENG 5229 or MECH ENG 5236 or MECH ENG 5238 or MECH ENG 5282, MIN ENG 2412, PHYSICS 2305 or PHYSICS 2311, STAT 5120 or STAT 5346 or STAT 5353.

4 Metallurgical Core Electives (9 hours): Core Elective I - Introduction to Metal Additive Manufacturing (MET ENG 5150) or Corrosion and Its Prevention (MET ENG 5310), Core Elective II - Steelmaking (MET ENG 4450) or Steels And Their Treatment (MET ENG 4320), Core Elective III - Intro to ICME (CER ENG 4410) or Phase Equilibria (CER ENG 3220) or Refractories (CER ENG 5250) or Chemistry and Inherent Properties of Polymers (CHEM 4810).

5 Technical Electives (MET ENG or approved listing)

6 Free Electives (3 hours)-algebra, trigonometry, basic ROTC, and courses considered remedial excluded

Laura Bartlett, Associate Professor
PHD Missouri Univeristy of Science and Technology

Arezoo Emdadi, Assistant Professor
PHD Missouri University of Science and Technology

Yijia Gu, Assistant Professor
PHD Pennsylvania State University

Simon Lekakh, Research Professor
PHD Belorussian Polytechnic Institute

F Scott Miller, Teaching Professor
PHD University of Missouri-Rolla

Michael Scott Moats, Professor
PHD University of Arizona

Joseph W Newkirk, Professor
PHD University of Virginia

Ronald J O'Malley, Professor
PHD Massachusetts Institute of Technology

David C Van Aken, Professor Emeritus[1]
PHD University of Illinois Urbana

Haiming Wen, Assistant Professor
PHD University of California-Davis

MET ENG 1017 Introduction To Metallurgical Engineering (LEC 1.0) Introduction to the field of metallurgical engineering with specific reference to the emphasis areas of extractive, manufacturing and physical metallurgy. The course will include lectures, videos and field trips to local industry.

MET ENG 1027 Computer Application In Metallurgical Engineering (LAB 1.0 and LEC 2.0)
Introduction to the use of microcomputers for simulation, data analysis including statistics, data acquisition from laboratory instruments, and automatic process control systems. The course will provide instruction in programming and software usage, and the laboratory will enable students to fully utilize the potential of microcomputer in later courses.

MET ENG 2001 Special Topics (LEC 0.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

MET ENG 2110 Metallurgy For Engineers (LEC 3.0)
Introduction to the structure and properties of metals and alloys and to processes used to modify the structure and properties of metallic materials, including alloying, deformation and heat treating. Prerequisite: Preceded or accompanied by Chem 1310, prior or concurrent.

MET ENG 2125 Microstructural Development Laboratory (LAB 1.0 and LEC 1.0)
Investigation of the relationships between microstructures, and processing for various materials. Prerequisite: Accompanied or preceded by Met Eng 3130.

MET ENG 2410 Applied Metal Forming (LAB 1.0 and LEC 1.0)
Introduction to the art and science of blacksmithing. Students to use forges to heat steel for shaping it. Techniques for shaping, cutting, chiseling, twisting, etc. Knowledge of hand and power tools and their use. Safety in the shop will be emphasized. History of blacksmithing will also be covered. Includes a lab portion which will work on projects. Prerequisite: Chem 1100.

MET ENG 3000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

MET ENG 3001 Special Topics (LAB 0.0 and LEC 0.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

MET ENG 3002 Cooperative Training (IND 1.0-2.0)
On-the-job experience gained through cooperative education in the field of metallurgical engineering with credit arranged through department cooperative advisor. A pass/fail grade will be given based on the quality of reports submitted and work supervisor's evaluation.

MET ENG 3120 Fundamentals Of Materials Behavior (LEC 3.0)
An introduction to crystal defects and deformation; mechanical testing; creep; fracture mechanics and fatigue. Prerequisite: "C" or better grade in both Met Eng 2110 and Civ Eng 2210.

MET ENG 3120H Fund Materials Behavior-Honors (LEC 3.0)

MET ENG 3125 Mechanical Testing of Materials (LAB 1.0 and LEC 1.0)
Deformation of materials and mechanical testing of materials; tensile testing, creep; impact testing; fracture mechanics and fatigue. Prerequisite: "C" or better in Met Eng 2110 and preceded or accompanied by Met Eng 3120.

MET ENG 3130 Metals Microstructural Development (LEC 3.0)
Fundamentals of microstructural developments as relating to solid solutions, solidification and transformations; phase diagrams; case studies. Prerequisites: "C" or better grade in MET ENG 2110; accompanied or preceded by CER ENG 3230.

MET ENG 3220 Introduction To Extractive Metallurgy (LEC 3.0)
Production and refining of metals by pyrometallurgy, hydrometallurgy, and electrometallurgy. Emphasis on heat and mass balance calculations for the unit processes of metals extraction. Introduction to the principles of combustion, heat utilization and recovery. Prerequisites: A grade of "C" or better in either Chem 1320 or Met Eng 1210. Preceded or accompanied by Met Eng 3330 or Cer Eng 3230 or Chem Eng 2110.

MET ENG 3225 Extractive Metallurgy Laboratory (LAB 1.0)
A series of laboratory experiments designed to illustrate the principles of pyrometallurgy, hydrometallurgy, and electrometallurgy. Prerequisite: Preceded or accompanied by Met Eng 3220.

MET ENG 3320 Transport Phenomena In Metallurgy (LEC 3.0)
The application of the principles of fluid flow and heat transfer to the solution of practical problems in metallurgical engineering. Prerequisite: "C" or better grade in Civ Eng 2200.

MET ENG 3330 Metallurgical Thermodynamics I (LEC 3.0)
Thermodynamic laws and thermodynamic functions and their relation to problems of metallurgical interest, thermochemistry, thermophysics, and chemical or phase equilibria. Prerequisite: Met Eng 1210 or Chem 1320.

MET ENG 3420 Principles Of Materials Processing (LEC 3.0)
An introduction to various methods of processing of metals and influences of processing on design. Includes: casting, welding, shaping, inspection and testing. Prerequisite: "C" or better grade in Met Eng 2110.

MET ENG 3425 Metals Processing (LAB 1.0)
Laboratory study of the methods of processing of metals. Prerequisite: Accompanied or preceded by Met Eng 3420.

MET ENG 4000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

MET ENG 4001 Special Topics (LEC 0.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

MET ENG 4002 Cooperative Training (IND 1.0-2.0)
On-the-job experience gained through cooperative education in the field of metallurgical engineering with credit arranged through department cooperative advisor. A pass/fail grade will be given based on the quality of reports submitted and work supervisor's evaluation.

MET ENG 4010 Seminar (IND 0.0-3.0)
Discussion of current topics.

MET ENG 4096 Materials Senior Design I (LEC 3.0)
Overview of the methods, approaches, and techniques required to execute materials related capstone senior design projects. Formation of teams, assignment of projects, review of department curriculum concepts and topics, and comprehensive project management skills needed to complete projects will be used as means to learn the design process. Prerequisites: Met Eng 3125 and Met Eng 2125, or Cer Eng 3315 with a "C" or better. (Co-listed with Cer Eng 4096).

MET ENG 4097 Materials Senior Design II (LAB 3.0)
A continuation of the Materials Senior Design I. Students working in groups will complete a capstone design project including process and product simulation and/or fabrication, safety aspects, environmental impact and capital and operating economics. Prerequisite: "C" or better in either Cer Eng 4096 or Met Eng 4096. (Co-listed with Cer Eng 4097).

MET ENG 4099 Undergraduate Research (IND 0.0-6.0)
Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

MET ENG 4320 Steels And Their Treatment (LEC 3.0)
Industrially important ferrous alloys are described and classified. The selection of proper heat treatments to facilitate fabrication and to yield required service properties in steels suitable for various applications is considered. Prerequisite: "C" or better grade in both Met Eng 3130 and Met Eng 2125.

MET ENG 4325 Ferrous Microstructures (LAB 1.0 and LEC 1.0)
Course provides an in-depth explanation of microstructural development during solidification, thermo-mechanical processing, and heat treatment of steel. Topics included: optical microscopy, quantitative metallography, the Fe-C phase diagram, solidification and banding, homogenization, grain size control, formation of microstructures upon heating/cooling. Prerequisite: A grade of "C" or better in Met Eng 2110.

MET ENG 4350 Process Metallurgy Applications (LEC 3.0)
Application of thermodynamics to process metallurgy. Equilibrium calculations with stoichiometry and heat balance restrictions, phase transformations, and solution thermodynamics. Use of thermodynamic software to solve complex equilibria in metallurgical applications. Prerequisite: "C" or better grade in Cer Eng 3230.

MET ENG 4420 Metals Casting (LEC 3.0)
An advanced course in the materials and methods used in modern metals casting processes. Application of metallurgical principles to the casting of metals. Design of castings and metals casting mold features using commercial casting process simulation software. Prerequisite: "C" or better grade in either Met Eng 3420 or Mech Eng 2653.

MET ENG 4420H Metals Casting-Honors (LEC 3.0-33)

MET ENG 4425 Metals Casting Lab (LAB 1.0)
A laboratory study of mold materials, metal flow, and cast metals. Emphasis is given to design of gating, risering, and ladle treatment techniques required for economical, high quality castings. Prerequisites: Accompanied or preceded by MET ENG 4420.

MET ENG 4450 Steelmaking (LEC 3.0)
Introduction to the fundamentals and unit processes used to turn impure iron and scrap into steel. Includes desulfurization, BOF and electric furnace operations, ladle metallurgy, casting, and stainless steel manufacture. Prerequisite: Grade of "C" or better in Cer Eng 3230 or Met Eng 3330.

MET ENG 4510 International Engineering and Design (LEC 3.0)
A multi-disciplinary engineering course focused on sustainable design and technology transfer to developing countries. Course includes elements of traditional capstone design classes. Experiential learning through competitions and/or field work is a major component of the class. Prerequisites: Senior standing, instructor approval, Geo Eng 5211, Geo Eng 5247. (Co-listed with Geo Eng 5092 and Cer Eng 4510).

MET ENG 4617 Metallurgical Process Design Principles (LEC 2.0)
Application of mass, component and energy balances for metallurgical design. The fundamentals of engineering economic analysis will be examined and experimental design techniques will be introduced. Students will be prepared for the selection and planning of the subsequent design project. Prerequisite: Senior standing in Met Eng.

MET ENG 4627 Metallurgical Design Project (LAB 2.0)
Student groups will undertake selected projects, which will represent a capstone design experience utilizing skills, understanding and data from previous courses. The faculty supervised open-ended design projects will involve a variety of tasks appropriate to the metallurgical engineer. Prerequisite: Met Eng 4617.

MET ENG 4637 Material Selection, Fabrication, And Failure (LEC 3.0)
Factors governing the selection of materials for specific needs, fabrication, heat treatment, surface treatment, and other aspects in the production of a satisfactory component. Failure analysis and remedies. Lecture plus assigned problems. Prerequisite: "C" or better grade in all of Met Eng 3130, Met Eng 2125, and Met Eng 3420.

MET ENG 5000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

MET ENG 5001 Graduate Special Topics (LEC 0.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

MET ENG 5040 Oral Examination (IND 0.0)
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/ comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

MET ENG 5099 Research (IND 0.0-15)
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

MET ENG 5110 High Temperature And Corrosion Resistant Alloys (LEC 3.0)
Fabrication and use of nickel, titanium, and refractory metal based alloys for use at high temperatures or in chemically corrosive environments. Properties and strengthening mechanisms of these alloys. Theory of high temperature oxidation and corrosion and design of alloys to prevent them. Prerequisites: Met Eng 3130, 2125.

MET ENG 5150 Introduction to Metal Additive Manufacturing (LEC 3.0)
Metal and alloys associated with Additive Manufacturing (AM). Issues with powders and wires as starting materials, safety, solidification mechanisms and development of microstructure and defects, AM part performance, and mechanical properties. Current alloys being utilized and future materials being developed. Prerequisite: Met Eng 2110.

MET ENG 5160 Mechanical Metallurgy (LEC 3.0)
Elastic and plastic behavior of metallic single crystals and polycrystalline aggregates. Resulting changes in mechanical properties are considered. Included are applications to metal fabrication. Prerequisites: Met Eng 3120, 3125, Civ Eng 2210.

MET ENG 5170 Nuclear Materials I (LEC 3.0)
Fundamentals of materials selection for components in nuclear applications. Design and fabrication of UO2 fuel; reactor fuel element performance; mechanical properties of UO2; radiation damage and effects, including computer modeling; corrosion of materials in nuclear reactor systems. Prerequisites: Civ Eng 2210; Nuc Eng 3205; Nuc Eng 3223; Met Eng 2110.(Co-listed with Nuc Eng 4241).

MET ENG 5171 Nuclear Materials II (LEC 3.0)
Extractive metallurgy of uranium, thorium, and zirconium. Equation of state of UO2 and fuel chemistry. LMFBR fuel and interaction of sodium and stainless steel. Materials for fusion and other advanced nuclear applications. Reprocessing of spent fuel and disposal. Prerequisite: Met Eng 5170.

MET ENG 5220 Recent Advances In Extractive Metallurgy (LEC 2.0)
A survey of extractive processes recently developed in the light of modern requirements with respect to raw materials, product quality, environmental impact, energy consumption, capital cost and process control. Prerequisite: Met Eng 4350.

MET ENG 5270 Mineral Processing II (Mechanics and Design) (LAB 1.0 and LEC 2.0)
Mineral particle mechanics of comminution, sizing, classification, concentration, filtering and thickening. Mill and equipment selection and design including flowsheet, development and plant assessment. Prerequisite: Min Eng 3412. (Co-listed with Min Eng 5424).

MET ENG 5310 Corrosion and Its Prevention (LEC 3.0)
A study of the theories of corrosion and its application to corrosion and its prevention. Prerequisite: A grade of "C" or better in either Chem Eng 3120 or Cer Eng 3230. (Co-listed with Chem Eng 5315).

MET ENG 5330 Nonferrous Alloys (LEC 3.0)
Structure and properties of nonferrous alloys (Al, Ti, Mg, Ni and Cu) are described. The role of processing and microstructure in the development of mechanical properties is emphasized. Prerequisite: Met Eng 3130 or Met Eng 5810.

MET ENG 5420 Advanced Metals Casting (LEC 3.0)
An advanced course in the materials and methods used in modern metals casting processes. Application of metallurgical principles to the casting of metals. Design of castings and metals casting mold features using commercial casting process simulation software. Prerequisite: Met Eng 3420 or Mech Eng 2653.

MET ENG 5425 Metals Casting Laboratory (LAB 1.0)
An advanced laboratory study of mold materials, metal flow, and cast metals. Emphasis is given to design of gating, risering, and ladle treatment techniques required for economical, highquality castings. Prerequisite: Accompanied or preceded by Met Eng 4420.

MET ENG 5430 Metals Joining (LEC 2.0)
Metals joining processes such as welding and brazing. Effects of welding on materials. Treatment and properties of welded joints. Welding defects and quality control. Prerequisite: Met Eng 2110 or 3420.

MET ENG 5440 Metal Deformation Processes (LEC 3.0)
An introduction to metal deformation concepts followed by a study of various forming processes from both the analytical and applied viewpoints. Processes to include: forging, wire drawing, extrusion, rolling, sheet metal forming, and others. Prerequisite: Met Eng 3120 and Met Eng 3420 both with "C" or better grade.

MET ENG 5450 Advanced Steelmaking (LEC 3.0)
This course is designed to provide students with an enhanced understanding of the chemistry and physics of ironmaking, steelmaking and casting, to apply these concepts to a wide range of problems in modern steelmaking and casting operations, and to perform advanced design and operational calculations associated with refining and continuous casting processes. Prerequisite: Grade of "C" or better in Cer Eng 3230 or Met Eng 3330.

MET ENG 5460 Metal Coating Processes (LEC 3.0)
Introduction to the current technologies used to enhance metal performance, particularly corrosion resistance, by overlay coatings. Deposition processes are emphasized and the fundamentals of the behavior of the films in high technology and electronic materials applications is discussed. Prerequisite: Senior or Graduate Standing.

MET ENG 5470 Ferrous Metals Casting (LEC 3.0)
An advanced study of the metallurgy of cast irons and net shape cast steel alloys. Includes theories of nucleation and growth in gray, nodular, compacted graphite and malleable irons. The effects of deoxidation practice and inclusion shape control for cast steels are also included. The effects of alloying elements, processing variables and heat treatment. Prerequisite: Met Eng 4420 or Met Eng 5420 or graduate standing with permission of instructor.

MET ENG 5480 Refining Of Metals (LEC 3.0)
Principles and applications of metal production by electrochemical methods. The course will address basic copper and zinc electrometallurgy. This includes discussion of anodes and anodic processes, cathode deposit control and contamination mechanisms, Faraday's Law and current efficiency, and current state of practice. Prerequisites: Cer Eng 3230, Met Eng 3220, graduate standing, or instructor approval.

MET ENG 5510 Nondestructive Testing (LEC 3.0)
Principles and applications of various means of non-destructive testing of metallic materials. Radiological inspection methods, ultrasonic testing, magnetic methods, electrical and eddy current methods and others. Prerequisite: Physics 2135 or 2111. (Co-listed with Elec Eng 5670).

MET ENG 5515 Nondestructive Testing Laboratory (LAB 1.0)
Application of radiological and ultrasonic methods of nondestructive testing of metallic materials. A radiographic X-ray units and ultrasonic equipment are used in the inspection of a variety of materials and manufactured parts. Prerequisite: Accompanied or preceded by Met Eng 5510.

MET ENG 5520 Electron Microscopy (LEC 3.0)
A course in the theory and application of both scanning and transmission electron microscopy and x-ray microanalysis. Topics considered are electron optics, image formation and analysis; x-ray generation, detection and analysis; and characterization of fracture surfaces. Prerequisites: Met Eng 3130 and Met Eng 2125, or a course in optical microscopy.

MET ENG 5525 Scanning Electron Microscopy Lab (LAB 1.0)
A course in the practical use and operation of scanning electron beam instruments and their associated techniques. Prerequisite: Preceded or accompanied by Met Eng 5520.

MET ENG 5620 Materials Behavior (LEC 3.0)
A course in crystal defects and deformation; mechanical testing; creep; fracture mechanics and fatigue. Prerequisites: Grade of "C" or better in both Met Eng 2110 and Met Eng 3120.

MET ENG 5630 Environmental Aspects Of Metals Manufacturing (LEC 3.0)
Introduction to environmental aspects of metal extraction, melting, casting, forming, and finishing. Subjects include history of environmental movement and regulations permitting, risk analysis, disposal and recycling of metal manufacturing residues, environmental ethics, environmental technologies and case studies. Prerequisite: Junior/Senior standing.

MET ENG 5810 Principles Of Engineering Materials (LEC 3.0)
Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Chem Eng 5300, Physics 4523, Cer Eng 5810).