

MATERIALS SCIENCE AND ENGINEERING (MATSE)

MATSE 81: Materials in Today's World

3 Credits

A survey of the properties, manufacture, and uses of polymers, ceramics, and metals in today's world with emphasis on modern developments and new materials. This course presents the basic science and technology of materials to non-science students. The course concentrates on 'Materials in Today's World' but frames the discussion in a relevant historical framework. Course topics are built around 'The Central Paradigm of Materials Science and Engineering,' which links processing to structures to properties to performance. First, students are introduced to the basic concepts of metals and nonmetals, and to a fundamental understanding of The Periodic Table. From these conceptual ideas, ceramics and electronic materials are rationalized on the basis of their electronic structures. The properties of materials, e.g., mechanical, thermal, electronic, and photonic, are developed directly from the structural knowledge of the materials classifications. The concept of materials design is introduced with respect to the properties of density, melting point, and hardness. Current practices for processing and manufacturing of materials are compared with methods that were employed in antiquity. This course meets the Bachelor of Arts: Natural Sciences (BA) and General Education: Natural Sciences (GN) Penn State requirements.

Bachelor of Arts: Natural Sciences

General Education: Natural Sciences (GN)

GenEd Learning Objective: Crit and Analytical Think

GenEd Learning Objective: Integrative Thinking

GenEd Learning Objective: Key Literacies

MATSE 101: Energy and the Environment

3 Credits

Energy utilization and technological development, energy resources, conversion and consequences on the local and global environment, and future energy alternatives. EGEE (MATSC) 101 Energy and the Environment (3) (GN)(BA) This course meets the Bachelor of Arts degree requirements. Energy is the life-blood of any society. The information and principles learnt in this course will allow the students to make sound judgments in the area of personal energy choices; There is increasing concern about the influence of human activities, particularly energy use, on global climate change. This has an impact on global business aspects. Students in all walks of life need to be exposed to the basic concepts to appreciate the positions of policymakers, scientists, and industry over the interrelationship between greenhouse gas emissions and global climate change. The students will acquire knowledge, which will enable them to critically evaluate any energy-related concerns of the society. This is important for any college graduate for responsible citizenship and stewardship. The main objectives of this course are to: provide basic understanding and appreciation of energy and environmental concepts and interconnectedness; analyze energy consumption patterns; discuss various energy resources that power the modern society; examine the energy conversion processes; explore interrelationships between energy use and industrial progress and environmental consequences; discuss future energy alternatives. Student performance will be evaluated continuously through homework

assignments, exams, group activities, class participation and a final examination. Position papers or term papers may be used in lieu of homework assignments in some sections. This course is a stand-alone General Education course.

Cross-listed with: EGEE 101

Bachelor of Arts: Natural Sciences

General Education: Natural Sciences (GN)

GenEd Learning Objective: Crit and Analytical Think

GenEd Learning Objective: Key Literacies

MATSE 101A: Energy and the Environment

3 Credits

Energy utilization and technological development, energy resources, conversion and consequences on the local and global environment, and future energy alternatives. EGEE (MATSC) 101A Energy and the Environment (3) (GN;IL)(BA) This course meets the Bachelor of Arts degree requirements. Energy is the life-blood of any society. The information and principles learnt in this course will allow the students to make sound judgments in the area of 'personal energy choices.' There is increasing concern about the influence of human activities, particularly energy use, on global climate change. This has an impact on global business aspects. Students in all walks of life need to be exposed to the basic concepts to appreciate the positions of policymakers, scientists, and industry over the interrelationship between greenhouse gas emissions and global climate change. The students will acquire knowledge, which will enable them to critically evaluate any energy-related concerns of the society. This is important for any college graduate for responsible citizenship and stewardship. The main objectives of this course are to: provide basic understanding and appreciation of energy and environmental concepts and interconnectedness; analyze energy consumption patterns; discuss various energy resources that power the modern society; examine the energy conversion processes; explore interrelationships between energy use and industrial progress and environmental consequences; discuss future energy alternatives. Student performance will be evaluated continuously through homework assignments, exams, group activities, class participation and a final examination. Position papers or term papers may be used in lieu of homework assignments in some sections. This course is a stand-alone General Education course. The course is currently offered in four sections every semester (Spring and Fall) with a total target enrollment of approximately 200-250 students per semester.

Cross-listed with: EGEE 101A

Bachelor of Arts: Natural Sciences

International Cultures (IL)

MATSE 112: Applied Materials Chemistry for Engineers

3 Credits

The goal of this course is to instruct students on how to apply the basic tenants of chemistry towards materials used for a variety of engineering applications as well as to provide an introduction to many of the core concepts of materials science and engineering. The course will begin with an in depth look at the fundamental intermolecular forces that pervade atoms, molecules, ions and dense materials and underlie the observed properties of materials with respect to environment. The course will then continue on to discuss crystal chemistry to teach students how to determine and interpret Miller indices and crystal structures as well as to express the relations between structure and material

properties. Thermodynamics and kinetics are then discussed with regard to reactions within inorganic chemistry and properties of inorganic materials with an emphasis on theoretical calculation and understanding of important concepts such as the Gibbs free energy and Fick's laws. The course will then cover electrochemistry, focusing on the fundamentals and relation to battery development and corrosion prevention before concluding with an overview of materials synthesis processing involving many of the previously addressed concepts.

Prerequisite: CHEM 110

General Education: Natural Sciences (GN)

GenEd Learning Objective: Crit and Analytical Think

GenEd Learning Objective: Integrative Thinking

MATSE 201: Introduction to Materials Science

3 Credits

Concepts of relationships between structure and thermal, optical, magnetic, electrical, and mechanical properties of metals, ceramics, glasses, and polymers.

Prerequisites: CHEM 112 or MATSE 112

MATSE 201H: Introduction to Materials Science

3 Credits

Concepts of relationships between structure and thermal, optical, magnetic, electrical, and mechanical properties of metals, ceramics, glasses, and polymers.

Honors

MATSE 202: Introduction to Polymer Materials

3 Credits

The materials science of organic or soft materials with an emphasis on synthetic and natural polymer. MATSE 202 Introduction to Polymer Materials (3) Materials made from many types of natural organic materials, (cotton, wool, hemp, leather, etc.) have been with us throughout recorded history and have played crucial roles in the rise of civilizations and the economies of tribes and nations. Over the course of the last 100 years or so the development of synthetic organic materials, particularly polymers, has transformed the way we live. Modern transportation systems, much of contemporary medicine and the entire electronics and computer industry would not be possible without these materials. In order to understand their nature and provide a basis for a more in-depth understanding of these materials provided by courses with a more specific focus, why they are ubiquitous in modern society, this course will provide students with a basic knowledge of the structure, synthesis and properties and processing of these materials, starting with a review of atomic and molecular structure and proceeding through basic elements of the chemical synthesis, structure, mechanical properties and processing of these materials. Students will discover the commonalities and differences between synthetic polymers, such as polyesters and nylons, and natural or biological polymers, such as cotton and silk. A comparison will also be made between the mechanical properties of "hard", inorganic materials such as metals and ceramics, and "soft", organic materials such as polymers. The primary intended audience is undergraduates in Materials Science and Engineering. This course will provide a necessary overview of organic materials for those students who will focus on inorganic materials in the major and also provide an introduction to organic materials for those students who will specialize in

polymers and other organic materials. It is also anticipated that students in other disciplines who want to obtain an overview of the science and engineering of organic materials would want to take this course.

Prerequisites: (CHEM 202 or CHEM 210) and (MATH 230 or MATH 231)

MATSE 203: Technical Communications

3 Credits

This course is a 3 credit general education course in technical writing, for undergraduates majoring in Materials Science and Engineering. In it, students will learn how to develop a variety of documents which they will be expected to write during the course of their college and professional careers, including technical/lab reports, posters, fellowship and internship applications, job search documents, progress reports, and formal and informal communications. Other topics would include ethics, literature surveys, critical evaluation of sources, citing of references, and proper data presentation. Embedded within each of these topics and document types will be instruction in the writing process, identifying and assessing your audience, organizing documents, adopting a professional style, learning active and passive voices, and using review and editing techniques.

Prerequisite: ENGL 15 or ENGL 30H or (ENGL 137H and ENGL 138T) and 3rd Semester or above

General Education: Writing/Speaking (GWS)

GenEd Learning Objective: Effective Communication

GenEd Learning Objective: Crit and Analytical Think

MATSE 219: Introduction to Materials Informatics

3 Credits

The proposed course has 5 modules. In the first module, the concepts of materials informatics are presented through spreadsheet software (e.g., Microsoft Excel) to enable the students practice with the content in a familiar environment. In the second module, computer programming is introduced (e.g., Python) and students learn to replicate tasks from Module 1 using this new tool. In the third module, various flavors of regression are introduced to model materials data, with special emphasis on ways that materials data is different from other data domains. In the fourth module, students learn to access publicly available materials data such as from published literature and online databases using simple APIs. In the final module, the concepts are linked to design and analysis of materials experiments including factorial design of experiments, outlier detection, and hypothesis testing. The overall intention is to provide students with basic skills in analyzing, modeling, and visualizing materials data using a programming language in preparation for the subsequent MATSE 419: Computational Materials Science and Engineering.

Prerequisite: MATH 141 Concurrent: MATSE 201 and MATH 220

MATSE 259: Properties and Processing of Engineering Materials

3 Credits

Relationship of structure and processing variables to the properties and service behavior of metals, polymers, and ceramics.

Prerequisite: EMCH 213 or EMCH 210

MATSE 297: Special Topics

1-9 Credits/Maximum of 9

Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

MATSE 297N: Special Topics - Inter Domain

1-9 Credits/Maximum of 9

Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest. This Special Topics is an Inter-Domain GenEd course

General Education: Humanities (GH)

General Education: Natural Sciences (GN)

General Education - Integrative: Interdomain

MATSE 400: Crystal Chemistry

3 Credits

Principles of crystal chemistry applied to structures, structural defects and properties of organic, inorganic, intermetallic, and metallic crystals.

Prerequisite: MATSE 201, MATSE 202, MATH 220, MATH 231, MATH 251

MATSE 401: Thermodynamics of Materials

3 Credits

The course starts with the first law of thermodynamics and its applications to the calculations of heat involved in various materials processes such as chemical reactions and phase transformations. Second law of thermodynamics and the concept of entropy are then introduced. The application of maximum work theorem to engine efficiency is briefly discussed. Various thermodynamic potentials are defined to determine the equilibrium of a system under various thermodynamic conditions, with an emphasis on the Gibbs free energy functions at constant temperature and pressure conditions. The relationships among thermodynamic properties are derived using the Maxwell relations. Phase diagrams of single-component systems are constructed from the Gibbs free energy function, and the Clapeyron equation is applied to describe the phase boundaries. Applications of thermodynamics to the determination of chemical equilibrium and to the calculation of the voltages of electrochemical reactions are also discussed. The last part of the course is focused on the solution thermodynamics and its application to binary phase-diagrams.

Prerequisite: MATSE 201 and MATSE 202 and (MATH 251 or (MATH 250 and MATH 252))

MATSE 402: Materials Process Kinetics

3 Credits

A treatment of process kinetics including chemical reaction kinetics and momentum, energy and mass transport.

Prerequisites: MATSE 201 and MATSE 202 and MATH 251

MATSE 403: Biomedical Materials

3 Credits

Describe properties of materials and composites and their in vivo interactions. BME 443 (MATSE 403) Biomedical Materials (3) Metals, polymers, and ceramics, and their composites, which are capable of emulating the functions of hard and soft tissues, are the subjects of this course. The subject matter shall be confined to implanted materials; external appliances, such as casts, braces, etc are not considered. The topical content of this course will be grouped into four areas. A general introduction to selected aspects of physiology will be presented. This will provide the background necessary to appreciate the factors which govern the selection of biomedical materials. Specific emphases will be placed on polymerization of biopolymers (polypeptides and polysaccharides) and the general relationships between conformation and biological function, the biochemistry of blood and blood surface interactions, the formation of teeth and bone and the relationships between microstructure, composition and function, the immune responses to implanted materials, the resorption of bone (osteoporosis) and the development of caries. The perspective placed on these topics will be that of materials science. The selection of ceramics for hard tissue prosthesis will be discussed. Orthopaedic and dental applications for ceramics will be discussed. Specific ceramic materials to be treated include dental porcelain, alumina- and zirconia-based ceramics, and bioglasses and pyrolytic carbons. Various classes of inorganic cements, gypsum, zinc phosphates, zinc carboxylates, silicates, and glassionomer cements will also be considered as ceramics. Hydroxyapatite, Hap-based composites and Hap-metal interactions will be discussed in particular. Relationships among physical properties, mechanical properties, and chemical interactions with biological fluids will be described. Dental and orthopedic applications of metals will be described. The fracture toughness of metals, their electrochemical responses in vivo, and the nature of the interfacial interactions with hard tissues will be treated. Dental amalgams and the noble metals for dental applications will be considered. Metals and alloys, such as Ti, Co-Cr, and vitallium, used in prosthetic applications, will be described and their properties and limitations discussed. The phenomenon of stress shielding and the immune responses associated with the accumulation of metallic and polymeric particular debris in the vicinity of an implant will be discussed in particular. Polymeric materials are important in a broad range of biomedical applications. Among these are soft tissue prostheses, hemostatic agents, dental restoratives, bone replacement materials, and surgical adhesives. In some applications it is desirable that a polymeric material biodegrade while in others property retention is desirable.

Enforced Prerequisite at Enrollment: (MATSE 201 or CHEM 112) and (MATH 230 or MATH 231)

Cross-listed with: BME 443

MATSE 404: Surfaces and the Biological Response to Materials

3 Credits

Focus is on special properties of surface as an important causative and mediating agent in the biological response to materials.

Enforced Prerequisite at Enrollment: CHEM 112 or MATSE 112

Cross-listed with: BME 444

International Cultures (IL)

MATSE 409: Nuclear Materials

3 Credits

Nuclear reactor materials: relationship between changes in material properties and microstructural evolution of nuclear cladding and fuel under irradiation. NUC E (MATSE) 409 Nuclear Materials (3) NUC E/ MATSE 409 provides a background on the types of materials used in nuclear reactors and their response to neutron irradiation. Most of the materials problems encountered in the operation of nuclear power reactors for energy production are discussed here. The objective of the course is to give nuclear engineering students a background in materials, so they understand the limitations put on reactor operations and reactor design by materials performance. In the first part of the course, we review basic concepts of physical metallurgy, to develop a mechanistic and microstructurally based view of material properties. In the second part of the course, we present the methods to calculate displacement damage to the material produced by exposure to neutron irradiation. The microstructural evolution that results from the reactor exposure (including radiation damage and defect cluster evolution, and changes) is described. The aim is to create a linkage between these changes at the atomistic level and the changes in macroscopic behavior of the material. Special attention is given to property changes that affect fuel performance and operational safety. Both mathematical methods and experimental techniques are emphasized so that theoretical modeling is instructed by experimental data. Students use the TRIM and SPECTER codes to quantitatively evaluate neutron damage, as well as learn simple analytical models that describe microstructural evolution and property changes under irradiation.

Enforced Prerequisite at Enrollment: PHYS 214

Cross-listed with: NUCE 409

MATSE 410: Phase Relations in Materials Systems

3 Credits

Phase rule; construction and interpretations of equilibrium diagrams; importance of nonequilibrium in materials. MATSE 410 Phase Relations in Materials Systems (3) This course integrates three core components of materials science and engineering: thermodynamics, kinetics, and interface crystallography in understanding processing and development of inorganic materials. It is the key course bridging the fundamentals to practical materials processing. Phase equilibria, phase diagrams, phase transformations and heat treatments are addressed in great details through nucleation, transformation kinetics, crystal interface and diffusion. The complexity of materials is discussed in hierarchy from pure elements, binaries, ternaries to multicomponents.

Prerequisite: MATSE 201, MATSE 401

MATSE 411: Processing of Ceramics

3 Credits

Principles of ceramic processing, including powder preparation and characterization, forming operations, and the basic phenomena underlying these operations. MATSE 411 Processing of Ceramics (3) This course covers the scientific and engineering principles of manufacturing of ceramic products. The course covers powder synthesis and characterization; surface and colloid chemistry; fabrication; and densification by sintering. There is an emphasis on the physical chemistry of particulate systems as relates to the various stages processing. The course is offered every fall semester and is required for

BS graduates of the Ceramic Science and Engineering option in Materials Science and Engineering. The course objectives are for the student to (1) become knowledgeable of all steps involved in ceramic manufacture from powder synthesis through final densification by sintering, (2) understand the rationale and compromises for selecting a given processing route, (3) understand and be able to apply the parametric relations for manufacture of a ceramic with a specified microstructure, and (4) understand the physical chemistry fundamentals responsible for the unique properties of fine powders.

Prerequisite: MATSE 400, MATSE 402

MATSE 412: Thermal Properties of Materials

3 Credits

Generation of high temperatures, measurement of temperature, heat transfer and furnace design, thermal stability of ceramic materials, applied thermodynamics. MATSE 412 Thermal Properties of Materials (3) The fundamentals of achieving, measuring, and controlling high temperature for materials processing are addressed. The crystal physics underlying heat capacity, internal energy, phonon and photon conduction, and thermal expansion is used to rationalize the behavior of a wide variety of ceramic and metallic materials in severe thermal environments. Micro- and macroscopic thermal transport, thermal shock and fatigue behavior, and thermochemical durability are addressed insofar as their impact on the design of, and with, high performance materials in thermostructural applications. Case studies on materials selection and design using the fundamentals of inorganic crystal chemistry, physics, thermodynamics, kinetics, elastic, and mechanical properties are widely employed. Students interested in disciplines such as metallurgy, ceramic science, electronic and photonic materials, mechanical engineering, aerospace engineering, industrial engineering, engineering science, and chemical engineering will benefit significantly from this course.

Prerequisite: MATSE 201 and MATSE 401

MATSE 413: Solid-State Materials

3 Credits

The main course objective is to provide sufficient background for the understanding of fundamental phenomena in solid state materials. Mathematical description of periodic arrays and the concept of reciprocal space are introduced, lattice vibrations are discussed. An introduction to quantum mechanics is given and the solution of the stationary Schrödinger Equation for various problems relevant in nanostructured materials is presented. A semi-quantitative approach is taken how the electronic structure of isolated atoms is changed as they bond and form molecules and solids. Emphasis is placed how such bonding influences whether the resulting material will be a metal, an insulator or a semiconductor. The goal is to master the modern framework in solid state materials that describes materials phenomena at an atomic level, such as electronic band structure and electronic transport, the vibrational properties of solid state materials and to prepare the audience for higher level quantum mechanical problems.

Prerequisites: MATSE 201 and MATH 220 and (MATH 231 or MATH 230)

MATSE 415: Introduction to Glass Science

3 Credits

Composition, melting, fabrication, properties, and uses of glass; combinations of glass with metals and other materials. MATSE

415MATSE 415 Introduction to Glass Science (3) This course aims to explain the unique characteristics of the glassy state, and to describe their role in the processing, application, and engineering performance of amorphous materials and glass products. The course teaches fundamental concepts of amorphous structure, and then utilizes them to establish structure-property relations in various glass systems. The viscosity, thermal expansion, chemical durability, strength behavior, and optical properties of silicate-based glasses are emphasized, although the important properties of phosphate, halide, and chalcogenide glasses are not overlooked. Also included are phenomenological descriptions of glass formation, liquid-liquid immiscibility, viscous flow, structural relaxation, stress relaxation, and crystallization in glass. Various methods for the synthesis of glass are reviewed (melting, CVD, and sol/gel), along with important manufacturing processes for commercial glass products. Throughout the course, the applications of glass and glass components in electronics, photonics, biomedicine, transportation, and energy are described to rationalize the use of glass (i.e., the materials selection), the specific glass composition, and the associated processing method.

Prerequisite: MATSE 401

MATSE 417: Electrical and Magnetic Properties

3 Credits

Electrical conductivity, dielectric properties, piezoelectric and ferroelectric phenomena; magnetic properties of ceramics. ESC 417 / MATSE 417 **Electrical and Magnetic Properties (3)** is designed to provide students with a fundamental understanding of the different responses a material can have to crapped electrical or magnetic fields. Important properties are introduced and correlated with knowledge of material chemistry, crystal structure, and microstructure to provide an understanding of the mechanisms responsible for controlling the observed properties, as well as the ways in which properties can be engineered. Electronic and magnetic properties encompass dielectric, ferroelectric, conductor, superconductor, and ferromagnetic materials. Material properties and structures are related to sensors, energy storage and conversion devices, biomedical devices and electronic components in telecommunications.

Enforced Concurrent at Enrollment: MATSE 400 and MATSE 413
Cross-listed with: ESC 417

MATSE 419: Computational Materials Science and Engineering

3 Credits

Introduction to computational material science and engineering. Overview of the computational methods for materials, from atomistic to the continuum scale. **MATSE 419 Computational Materials Science and Engineering (3)** Modeling is a critically important tool in the field of materials. This course is designed to inform students about all areas of materials modeling, and to explore the use of modeling in different research areas. This is a hands-on undergraduate level course, mandatory for all MATSE students, covering current methods for modeling soft and hard matter, at the atomistic, meso and continuum scale levels. It consists of an overview of individual techniques of modeling from atomistic molecular dynamics and Monte Carlo, coarse-grained molecular dynamics, and multiscale modeling, to the continuum (e.g. SAFT, CALPHAD). It also includes a computer laboratory component with hands-on exercises. At the conclusion of the course, students will understand the physical basis and basic procedures of each technique. Students will be able to understand the general literature in modeling and its connection with experimental work, as well as to communicate with experts in the field. From the laboratory practices, they will learn how the

individual modeling techniques contribute to knowledge in each area, and to interconnect them with experimental information.

Prerequisite: CMPSC 200 and MATSE 201 and MATSE 202 and MATH 220 and (MATH 231 or MATH 230) and MATH 251
Cross-listed with: CMPMT 419

MATSE 421: Corrosion Engineering

3 Credits/Maximum of 3

Industrial forms of corrosion and preventive methods, and their description in terms of basic thermodynamic and kinetic considerations. **MATSE 421 Corrosion Engineering (3)** This 3-credit course is an introduction to the corrosion field and more broadly to the principles of electrochemistry and to the electrode reactions that occur during the undesirable corrosive degradation of metal, and also in various important commercial processes such as electroplating, electroless plating, battery and fuel cell operation, aqueous extraction metallurgy and corrosion prevention techniques. The objectives of this course are to introduce the student to the (1) principles of electrode reactions, (2) nature of commercial corrosion resistant alloys and their compositions, (3) various forms of corrosion and preventative measures, and (4) design of electrochemical laboratory and field procedures for detecting corrosion processes and determining their rates. Thermodynamic and rate data are used to make engineering decisions relative to the occurrence of corrosion, to the effectiveness of the various preventative measures, and to electrochemical design. Corrosion processes and electrode reactions more generally are primarily concerned with the surface properties of materials, but the bulk properties, such as microstructure, grain size, hardness, and composition, are discussed in terms of their impact on materials degradation. In-class closed-book exams and problem sets, and homework that allow student collaboration, are used for evaluation. Computer access to the course is available and includes all lecture material, old exams with answers, home works, and syllabus on the Web. This course is offered every year with typical class size of less than 20 students.

Prerequisites: PHYS 212, MATSE 401, MATSE 402

MATSE 422: Thermochemical Processing

3 Credits

Physico-chemical aspects of high temperature extraction and processing of metals and alloys. Design and evaluation of processes and process options. **MATSE 422 Thermochemical Processing (3)** An important goal of materials engineering is to efficiently produce metals and alloys of specific composition. Familiar examples include the tonnage production of metals and alloys, the production of ultra high purity electronic materials such as silicon and germanium, and the deposition of thin films for various applications. In this course the students get an understanding of the physical and chemical principles underlying these operations and how these principles are applied in industrial practice. The students get ample opportunities to apply thermodynamics, kinetics, and transport phenomena to understand why the processes currently in use work. Furthermore, they learn how to marshal information for the design of projected new processes and process options. Broadly stated, the topics include solid-state reactions, production of liquid metals, and processing, all carried out at high temperatures. The topics are covered in a set of lecture notes available from the instructor. The lectures are accompanied by about fifteen problems sets in the form of home work and class work so that the students experience first-hand how the principles of thermodynamics

and rate processes are applied in solving important problems in thermochemical processing.

Prerequisite: MATSE 401, MATSE 402

MATSE 425: Processing of Metals

3 Credits

Modern methods of shaping metals in liquid and solid states: casting, joining, powder and deformation processing. Design of new technology. MATSE 425 Processing of Metals (3) This course focuses on how metals and alloys may be processed into different shapes and how those processing procedures affect the metallurgical microstructure and properties. Consideration of shape, the alloy composition, and property goals are all factors in selecting an optimum processing 'window'. Such carefully selected processing conditions not only produce the desired component shape in a cost-efficient manner but also ensure acceptable properties and safe in-service performance. This course surveys the following metal processing procedures: (a) solidification processing, (b) heat

Prerequisite: MATSE 402

MATSE 426: Aqueous Processing

3 Credits

A study of the chemical and engineering principles pertinent to metal processing in aqueous systems: hydrometallurgical extraction, plating, materials preparation. MATSE (MN PR) 426 Aqueous Processing (3) This 3-credit course deals with the chemical and engineering principles underlying the aqueous processing of metals: metal extraction from primary and secondary sources, electroplating, and metal finishing, powder synthesis, energy storage and conversion, and treatment of recycling of metal-containing toxic wastes. 1. Physico-Chemical Principles - Thermodynamic, chemical kinetic and transport factors which control hydrochemical processes (leaching; precipitation; adsorption; solvent extraction; ion exchange; electrowinning, electrorefining and electroplating; membrane processes; energy storage and conversion); graphical representation of homogeneous and solid/solution equilibria; chemical reagents. 2. Engineering Principles - Reactor design and staged operations; ideal batch, continuous stirred-tank and plug-flow reactors; fluidized bed reactors; electrochemical reactors; multistage separation processes (solid-liquid, liquid-liquid, and gas-liquid systems). 3. Process Synthesis - Design of metal separation (extraction, refining, waste treatment) materials synthesis, metal finishing, and energy storage/conversion processes and system-integration of unit operations, industrial practice. Emphasis on closing circuits to minimize or eliminate waste effluents.

Enforced Prerequisite at Enrollment: EME 301 or MATSE 401
Cross-listed with: MNPR 426

MATSE 427: Microstructure Design of Structural Materials

3 Credits

The focus of this course is on understanding the microstructure development and design of structural ferrous metals. The course will begin with understanding the basic physical metallurgy concepts of ferrous metals and applying these principles to understanding their processing/structure/property relationships. Specifically, the alloying principles, phase transformation behavior, and transformation kinetics steels will be considered in detail. Heat treatment practices (annealing,

normalizing, quenching, tempering, and precipitation hardening) and their effects on the microstructure and mechanical properties of each of these metals will also be studied.

Prerequisite: MATSE 201 or MATSE 259

MATSE 429: Non-Ferrous Structural Metals

3 Credits

The focus of this course is to understand the phases, microstructures, and mechanical properties of non ferrous structural metals; specifically the alloys of aluminum, titanium, nickel, and copper. The alloying principles, phase transformation behavior, and transformation kinetics for each metal system will be considered in detail. Heat treatment practices (annealing, normalizing, tempering, aging, and precipitation hardening) and their effects on the microstructure and mechanical properties of each of these metals will also be studied. Corrosion resistance, weldability, and sustainability will also be considered for the alloy systems.

Prerequisite: (MATSE 201 or MATSE 259) and 6th semester standing

MATSE 430: Materials Characterization

3 Credits

Elements of crystallography and the characterization of crystalline and non-crystalline materials using x-ray diffraction, electron microscopic, and other instrumental techniques. MATSE 430 Materials Characterization (3) This course will introduce students to characterization techniques for quantifying microstructure, chemistry and atomic structure of solid state materials. Elastic and inelastic interactions of radiation (e.g. electromagnetic and electrons) with solid state materials are the basis for most characterization techniques. Utilizing these interactions it is possible to obtain structural and chemical information from materials, often at small length scales. In this course, students will be introduced to the most common imaging, diffraction and spectroscopy techniques used for materials characterization. They will develop an understanding of the underlying physics behind the techniques to enable interpretation of the data. The course will be beneficial for any student interested in solid-state materials, as it provides a key component of the processing-structure-properties process.

Prerequisites: MATSE 201 and MATSE 202 and MATH 220 and (MATH 230 or MATH 231) and MATH 251

MATSE 435: Optical Properties of Materials

3 Credits

Electromagnetic spectrum, interaction of light with materials, color, thin film optical coatings, electro-, integrated and nonlinear optics.

Prerequisite: MATSE 400

MATSE 436: Mechanical Properties of Materials

3 Credits

Fundamental relationships between structure and mechanical behavior of materials. MATSE 436 Mechanical Properties of Materials (3) The topics covered in this course are essential to students in the Materials Science and Engineering options, and these are also required for materials engineering courses nationally accredited by the professional societies.

The course is taught at the 400 level because it requires the fundamental courses in mathematics and physics to be completed. The course also requires completion of an introductory course in materials science. This new course typically fits into the junior or senior year, when students in the major are understanding how the properties of materials can be changed by controlling the structure of materials. The course has also been designed such that students in other engineering majors can take this course as a technical elective. Some of the information in this course is used in laboratory courses for the major. The course is not required as a prerequisite for other courses.

Prerequisite: (MATSE 201 or MATSE 259) and MATSE 202 and MATH 220 and (MATH 231 or MATH 230) and MATH 251 and PHYS 211

MATSE 440: Nondestructive Evaluation of Flaws

3 Credits

Methods and limitations of nondestructive evaluation of mechanical flaws; optical, acoustical, electromagnetic, x-ray, radiography, thermography, and dye techniques.

Enforced Prerequisite at Enrollment: EMCH 213 or EMCH 210H or EMCH 210

Cross-listed with: EMCH 440

MATSE 441: Polymeric Materials I

3 Credits

This 3-credit course focuses on about 50 commercially most important polymers together with the discussion of synthesis routes, industrial production processes, processing methods, physical and chemical properties, and applications. They are classified into 10 families of polymeric materials, which are taught along with introduction of polymeric materials and synthesis of polymers in the beginning of the class.

Prerequisite: (CHEM 202 or CHEM 210) and MATSE 202 and (MATH 231 or MATH 230)

MATSE 445: Thermodynamics, Microstructure, and Characterization of Polymers

3 Credits

The properties of individual polymer chains will be studied and characterized, including theoretical and experimental techniques pertaining to the characterization of polymeric microstructure. This course develops fundamental understanding of microstructures and chain conformations of polymers. Polymer synthesis, including step-growth and chain polymerizations. The kinetics of polymerization will be considered along with the thermodynamics of polymer solutions and blends.

Prerequisite: MATSE 202

MATSE 446: Mechanical and Electrical Properties of Polymers and Composites

3 Credits

This course is an introduction to the mechanical and electrical properties of polymers and polymer-based composites: The main focus is on the importance of molecular structure, rubber elasticity, mechanisms of yielding, viscoelasticity, and the manifestation of the static and

ac dielectric properties, as well as conduction. The course topics include polymer chain structures and characterization methods, the amorphous state (glass transition), the crystalline state (including X-ray diffraction, degree of crystallinity, and kinetics), polymer networks and gels, mechanical properties, and electrical properties.

Prerequisite: MATSE 202

MATSE 447: Rheology and Processing of Polymers

3 Credits

Fluid Mechanics: Stress, strain, tensors, viscosity, modulus, conservation of mass, momentum transfer, Navier-Stokes equations, Reynolds number, creeping flow, Poiseuille flow, Couette flow, dimensional analysis and scaling. Rheology: Linear viscoelasticity, stress relaxation, oscillatory shear, creep and creep recovery, Boltzmann superposition, nonlinear viscoelasticity, steady shear, normal stresses, transient shear flows, rotational rheometers, capillary/slit rheometers, simple nonlinear viscosity models, time-temperature superposition, molecular models, entanglement, crosslinking reactions (gelation), extensional flows. Processing: Extrusion, pumping, mixing, screw design, die design, die swell, injection molding, mold filling, computer-aided mold design, weld lines, compression molding, sheet extrusion, thermoforming, pipe extrusion, blow molding, film blowing, rotational molding, fiber spinning, profile extrusion, coating reaction injection molding.

Prerequisite: MATSE 202

MATSE 449: Fundamentals of Composite Materials Science and Engineering

3 Credits

MATSE449 Fundamentals of Composite Materials Science and Engineering covers the fundamental science and engineering of multicomponent materials, with special emphasis on Polymer Matrix Composites. Topics include the design, materials selection, interfaces/interphases, processing, life cycle analysis (of environmental impacts), and properties of these materials. The course works up from atomic and molecular forces, through interfacial interactions, towards stress transfer at interfaces and mechanical properties of composites. Advanced Topics are a major part of the course and are selected from current industrial and commercial examples of composites, such as nanocomposites and nanofillers in composites, non-thermoplastic (rubber/ceramic/metal) matrix composites, life cycle analysis of specific systems, biomimetic and biopolymer composites, etc.

Enforced Prerequisite at Enrollment: MATSE 201 and MATSE 202 (or equivalent introductory course on materials)

MATSE 450: Synthesis and Processing of Electronic and Photonic Materials

3 Credits

The materials science of applying thin film coatings, etching, and bulk crystal growth; includes materials transport, accumulation, epitaxy, and defects.

Enforced Prerequisite at Enrollment: (MATSE 201 or ESC 414M) and Sixth Semester standing
Cross-listed with: ESC 450

MATSE 455: Properties and Characterization of Electronic and Photonic Materials

3 Credits

Materials characterization in general; electrical properties of crystals, contacts, films; optical properties of single phase materials, waveguide, and multilayer stacks.

Prerequisite: MATSE 201 or ESC 414M, ESC 314

MATSE 460: Introductory Laboratory in Materials

1 Credits

An introduction to comparative physical properties and characteristics of various materials including mechanical, electrical thermal, and structure/morphology. MATSE 460 Introductory Laboratory in Materials (1) This is a lab course whose goal is to provide an integrated approach to materials science and engineering. Any individual lab will consist of a number of elements, initially students will be provided with a presentation summary of the proposed lab. This could be film, video, web delivery, hard copy or live presentation. Presentation time will be limited but should be reviewed before students attempt the hands-on lab. All labs will examine a variety of different materials including metal, ceramics and polymers. Labs will be integrative in the sense that they will include use of spreadsheets, data plotting, and presentation of results as written reports and/or as a "PowerPoint" presentation. The labs selected have been chosen specifically because they cut across all current basic materials disciplines. These labs are intended to provide students with a broad appreciation of the range and contrast of material structures and properties, in order that students more fully appreciate the breadth of material science and engineering.

Prerequisite: MATSE 201 and MATSE 202

MATSE 462: General Properties Laboratory in Materials

1 Credits

An introduction to comparative physical properties of various materials including mechanical, thermal electrical properties and the measurement of said properties. MATSE 462 General Properties Laboratory in Materials (1) This is a lab course whose goal is to provide an integrated approach to physical property measurements in materials science and engineering. Any individual lab will consist of a number of elements, initially students will be provided with a presentation summary of the proposed lab. This could be film, video, web delivery, hard copy or live presentation. Presentation time will be limited but should be reviewed before students attempt the hands-on lab. All labs will examine a variety of different materials including metal, ceramics, polymers and composites. Labs will be integrative in the sense that they will include use of spreadsheets, data plotting, and presentation of results as written reports and/or as a 'PowerPoint' presentation. The labs selected have been chosen specifically because they cut across all current basic materials disciplines. These labs are intended to provide students with a broad appreciation of the range and contrast of material properties and the measurement of such properties, in order that students more fully appreciate the breadth of material science and engineering.

Prerequisite: MATSE 460

MATSE 463: Characterization and Processing of Electronic and Photonic Materials Laboratory

1 Credits/Maximum of 1

Provides experience with key processing methods for EPM materials and advanced characterization methods for EPM materials and simple device structures.

Prerequisite: MATSE 400, MATSE 430, MATSE 450, MATSE 455, MATSE 460; Concurrent: MATSE 450, MATSE 455

MATSE 468: Ceramics Laboratory III

1 Credits

Ceramic processing and powder characteristics. MATSE 468 Ceramics Laboratory III (1) This course will demonstrate to students the experimental techniques by which the key powder characteristics and powder processes are determined, how to analyze the data from the measurements, and to reveal the interaction between properties, processing and structure. The course concentrates on the importance of powder characterization, forming techniques, sintering and microstructure characterization in the processing of ceramics.

Prerequisite: MATSE 462 Concurrent Courses: MATSE 411

MATSE 471: Metallurgy Processing Laboratory

1 Credits

A laboratory integrating experimental aspects of the material contained in MATSE 425, casting, solidification micro-structures heat treating, welding, etc. MATSE 471 Metallurgy Laboratory I (1) This course is largely a metals processing laboratory focused on casting, metal deformation, heat treating, and welding. Understanding how these processes affect microstructure and properties will be studied.

Prerequisite: MATSE 462 Enforced Concurrent at Enrollment: MATSE 425

MATSE 473: Polymeric Materials Laboratory

1 Credits

Principles and practices of polymerization, including condensation, free radical (bulk, solution, suspension, emulsion), ionic, and Zeigler-Natta procedures. MATSE 473 Polymeric Materials Laboratory--Synthesis (1) This laboratory course provides students exposure to a variety of synthetic techniques basic to Polymer Science. From the polymerization of styrene to the preparation of urethane foams, students will see the role varied synthetic methods and chemistries play in determining the final form and properties of a given polymer. Students also learn the polymer structure characterization by examining the produced polymers with proper tools and instruments.

Prerequisite: MATSE 202 and MATSE 462

MATSE 475: Particulate Materials Processing

3 Credits

Fundamentals of processing particulate materials including production, characterization, handling, compaction, and sintering of metal, carbide, intermetallic, and composite powders.

Enforced Prerequisite at Enrollment: EMCH 315 or ESC 414M or MATSE 259

Cross-listed with: ESC 475

MATSE 483: Simulation and Design of Nanostructures

3 Credits

Introduction to computer simulation techniques and their applications at the physical/life sciences interface. E SC (MATSE) 483 Simulation and Design of Nanostructures (3) Students will learn the simulation techniques and the design rules of nanostructures. Basic concepts of computer modeling will be introduced using quantum and classical approaches. Fundamental physical phenomena encountered in the molecular fields of computational physics, chemistry, and biology will be studied. Applications are drawn from a broad range of fields including soft and condensed matter to build an understanding of nanostructures. The course will assume knowledge and skill developed in the prerequisite courses of PHYS 214 and MATH 230. Students are expected to combine knowledge from other courses with information presented here to develop sophisticated interpretations and understanding of physical and chemical principles of nanostructures and their design rules. Evaluation methods to be used in this course will be two in-class examinations and one final period examination. The course contains a computer code generation and implementation component. Students will use commercial or educational computer codes (e.g. Matlab, Mathematica, AMBER, CHARMM, VASP, etc.) which are available at our high performance computing clusters (<http://gears.aset.psu.edu/hpc/>) Students will use the computing clusters to perform simulations which are accessible from any classroom or laboratory at Penn State. The principal objectives of the course is to learn the fundamental physics of nanostructures and to design them with computer simulations. This approach starts from classical molecular dynamics that apply on the large scale biological and synthetic assemblies and encompasses quantum mechanics for the molecular and atomic sizes. This course will give a broad scientific picture of simulation techniques in the area of nano-science and technology.

Prerequisite: PHYS 214 or ESC 312, MATH 230

Cross-listed with: ESC 483

MATSE 492W: Materials Engineering Methodology and Design

3 Credits

Designed to familiarize students with the literature and technology developments in the use of, and design with, materials in industrial applications. MATSE 492 Materials Engineering Methodology and Design (3) The objective of this course is to teach students the skills to solve realistic problems related to the use of materials in industrial practice. This will be accomplished by considering alternatives for materials design or selection and proposing the most effective scientific or engineering solutions. The methodology will take into account other forces acting on the design process, such as economic, environmental, sustainability, manufacturability, ethical, health and safety, social and political concerns. Students will develop these design skills by working in teams on projects defined by industry, and will learn to communicate their solutions in verbal and written form. Students will also learn the key features needed in developing a team approach to solving problems. Typically, evaluation is based on written reports, performance in presentations, and instructors's assessment of the student's participation in design team activities. At the conclusion of the course, each student will select a design or independent research topic for their capstone senior-year design project.

Prerequisite: MATSE 201, MATSE 202, MATSE 436, sixth semester standing in Materials Science and Engineering Writing Across the Curriculum

MATSE 493W: Materials Science and Engineering Multidisciplinary Capstone Design Project

3 Credits

This course focuses on multidisciplinary industry-sponsored and community service-based design projects offered in conjunction with the College of Engineering's Learning Factory. MATSE 493W Materials Science and Engineering Multidisciplinary Capstone Design Project (3) This course will provide students with the opportunity to learn the design process in the context of an industry-sponsored or community service-based design project that demands they produce a working solution. The design projects in this course will be structured for students from two or more different engineering majors, as defined by the project sponsors in collaboration with the instructor and departmental project coordinators. The project sponsor will provide the technical expertise for the project, a clear definition of all project deliverables that are expected, and the financial support to cover needed materials and supplies and travel costs. Project sponsors will be invited to attend the Project Kickoff at the start of the semester to present their ideas and answer questions from the students as well as the Design Showcase at the end of the semester where teams display their results to the project sponsors and the public. The Center for Engineering Design and Entrepreneurship (CEDE) in Hammond Building and the Bernard M. Gordon Learning Factory will provide the facilities where the design teams can work together to develop the design concept and prototype solutions. Faculty members in the School of Engineering Design, Technology, and Professional Programs (SEDAPP) will administer the course, including reading, evaluating, and grading the final project report, provide lectures on topics including on project management, design, product manufacturing, intellectual property, engineering ethics, societal/global/contemporary/professional issues, and related technical topics, and organize invited technical lectures related to industry projects. In accordance with standard Learning Factory procedures, specific multidisciplinary projects will be selected for this course to provide challenging senior-year design experiences for all students, and the Director of the Learning Factory will coordinate the selection of these projects with the course instructor prior to the start of each semester of the course offering. Multidisciplinary teams will be formed based on specific project needs (i.e., expertise from two or more disciplines based on the project scope).

Prerequisite: MATSE 492W Writing Across the Curriculum

MATSE 494M: Research and Design Senior Project

1-3 Credits/Maximum of 3

Continuation of a research problem in materials culminating in a bound thesis describing the work.

Honors Writing Across the Curriculum

MATSE 494W: Research and Design Senior Project

1-3 Credits/Maximum of 3

MATSE 494W Research and Design Senior Project (2) This course continues the senior thesis research topic addressed by the student in MATSE 493W. This is a capstone research/design project which

integrates: a) background literature search with articulation of a research hypothesis, b) design and implementation of an experimental plan to test the hypothesis, and c) conclusions regarding the validity of the hypothesis based on the experimental data obtained in the course of the research. The main characteristic of this course is the performance of the research plan articulated in MATSE 493W, followed by interpretation of the data in the context of the original hypothesis(es). Laboratory research is generally performed in collaboration with faculty and graduate research assistants, using equipment and facilities in a wide range of laboratories throughout campus. Occasionally, the nature of the research may require the student to collaborate with researchers outside of Penn State, perhaps even spending some time in residence at other facilities. The course culminates in the preparation of a bound thesis detailing the relevance and findings of the research. Assessment of the student's progress is via grading of all components of the thesis (literature review/background, statement of the problem, design of the experimental plan, results and discussion, conclusions, recommendations for future work, and references/appendices), as well as the diligence of the student in performing the experimental research in a professional and timely fashion. The course is offered each semester to allow for differing schedules for students following the conventional MATSE curriculum versus those who have elected to participate in the Cooperative Education program.

Writing Across the Curriculum

MATSE 496: Independent Studies

1-18 Credits/Maximum of 18

Creative projects, including research and design, which are supervised on an individual basis and which fall outside the scope of formal courses.

MATSE 496H: Independent Studies

1-3 Credits/Maximum of 3

Creative projects, including research and design, which are supervised on an individual basis and which fall outside the scope of formal courses.

Honors

MATSE 497: Special Topics

1-9 Credits/Maximum of 9

Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.