MATERIALS SCIENCE AND ENGINEERING (MSE)

MSE 0099 Undergraduate Research and/or Independent Study
An opportunity for the student to become closely associated with a professor (1) in a research effort to develop research skills and technique and/or (2) to develop a program of independent in-depth study in a subject area in which the professor and student have a common interest. The challenge of the task undertaken must be consistent with the student's academic level. To register for this course, the student and professor jointly submit a detailed proposal to the undergraduate curriculum chairman no later than the end of the first week of the term. Note: a maximum of 2 c.u. of MSE 099 may be applied toward the B.A.S. or B.S.E. degree requirements. Open to all students.
Fall or Spring
1-4 Course Units

MSE 2010 Materials Lab I
This is the first of three 0.5 CU required laboratory courses in the undergraduate MSE program. This course will focus on applying introductory materials science principles, in tandem with those from prior physics and chemistry courses, to study the properties of metals, polymers, and glasses. Students will apply many of the concepts that are taught in the concurrent course, MSE 2150. Hands-on laboratory skills that will be developed include thermal testing and characterization, optical microscopy and scanning electron microscopy (SEM), mechanical testing, effects of thermal treatment on material properties, and the basics of MATLAB applied to lab work. In addition, students will develop professional skills regarding working safely and effectively in a team-based laboratory setting, basics of statistics and error analysis, and analyzing and presenting data in written reports and presentations. ENGR 105 recommended.
Fall
Prerequisite: ENGR 1050 AND CHEM 1011 AND MSE 2200
Corequisite: MSE 2200
.5 Course Units

MSE 2020 Materials Lab II
This is the second of three 0.5CU required laboratory courses in the undergraduate MSE program. This course will build on the experimental and professional skills introduced in MSE 201 and will reinforce concurrent lecture courses in materials thermodynamics and optoelectronics of materials. Hands-on experimental skills to be developed include phase transformations in metals and characterization using electron microscopy image analysis, thin-film fabrication methods and measurement techniques, nano-materials synthesis (including quantum dot technologies) and characterization of size and optical properties, and characterization of next-generation photovoltaic materials. Students will expand on their MATLAB skills for image analysis, I-V curve plotting, and presentation of high-quality figures for technical reports and presentations. Students will also be exposed to material life-cycle analysis, device sensitivity, and sustainability and how they each apply to materials design.
Spring
Prerequisite: MSE 2010 AND MSE 2150 AND MSE 2600
Corequisites: MSE 2150, MSE 2600
.5 Course Units

MSE 2150 Introduction to Functional Materials: From Macro to Nanoscale
The purpose of this course is: 1) to introduce key concepts underlying the design, properties and processing of functional materials and their applications, and 2) to apply these concepts in the rapidly growing field of nanomaterials and nanotechnology. Fundamental chemical and physical principles underlying electronic, dielectric, optical and magnetic properties will be developed in the context of metals, semiconductors, insulators, crystals, glasses, polymers and ceramics. Miniaturization and the nanotechnology revolution confronts materials science with challenges and opportunities. Examples in which nanoscale materials exhibit qualitatively different properties compared to bulk will be emphasized.
Spring
Prerequisite: MSE 2210
1 Course Unit

MSE 2200 Introduction to Materials Science and Engineering
The course is an introduction to the most important concepts in materials science and engineering. You will learn how the control of chemical bonding, synthesis, processing, structure and defects can be used to tailor the properties and performance of materials for applications that range from sustainable sources of energy, to construction, to consumer electronics. Case studies are also included to highlight environmental issues associated with materials degradation. This course includes lab demonstrations of key materials properties and a final project where students research an area of materials technology of their own interest.
Fall
Also Offered As: MEAM 2200
Prerequisite: CHEM 1011 OR PHYS 0140 OR MEAM 1100
1 Course Unit

MSE 2210 Quantum Physics of Materials
This course develops the background in basic physics required to understand the behavior of electrons in atoms, molecules and solids. Beginning with experiments and ideas that led to the foundation and postulates of Quantum Mechanics, the behavior of an electron in simple potential wells is treated. The electron in a harmonic oscillator well and the Coulomb potential of a hydrogen atom are treated next. Pauli’s exclusion principle and generalization to multi-particle systems are introduced. The Fermi energy, density of states and free electron band structure will be introduced. Many state-of-the-art materials analysis techniques will also be demonstrated throughout the course.
Fall or Spring
Prerequisite: (PHYS 0140 OR PHYS 0150) AND MATH 2400
1 Course Unit
MSE 2500 Nano-scale Materials Lab
In this class you will learn laboratory methods used to synthesize materials, to examine the structure of materials, to measure electrical, mechanical and thermal properties, and to investigate the relationships between processing, structure and properties. Emphasis is placed on laboratory skills, technical understanding, and technical communications (figures, writing). The laboratory exercises involve: 1) learning how to use state of the art equipment for studying the properties and internal structure of materials, 2) qualitative and quantitative interpretation of data and observations, and 3) the development of analytical skills necessary to form general and fundamental conclusions from observations and data. This course focuses on how materials’ structure and chemistry can be controlled to tailor properties and how properties of nanoscale materials can differ significantly from their bulk counterparts.

Prerequisite: MSE 2200
1 Course Unit

MSE 2600 Energetics of Macro and Nano-scale Materials
Basic principles of chemical thermodynamics as applied to macro and nano-sized materials. This course will cover the fundamentals of classical thermodynamics as applied to the calculation and prediction of phase stability, chemical reactivity and synthesis of materials systems. The size-dependent properties of nano-sized systems will be explored through the incorporation of the thermodynamic properties of surfaces. The prediction of the phase stability of two and three component systems will be illustrated through the calculation and interpretation of phase diagrams for metallic, semiconductor, inorganic systems.

Spring
Prerequisite: CHEM 1021
1 Course Unit

MSE 2960 Study Abroad
1 Course Unit

MSE 3010 Materials Lab III
This is the third of three 0.5CU required laboratory courses in the undergraduate MSE program. The culmination of the lab program, this course will focus on applying advanced materials science principles taught in concurrent lecture courses to crystallographic techniques and analysis, and to measurements of polymers and soft materials. Students will employ many of the experimental and professional skills developed in past lab experiences; new hands-on laboratory skills to be covered include synthesis of ceramic super-conductor materials and effects of processing on properties, X-ray diffraction and X-ray scattering, and surface modification and contact angle measurements. Students will also be responsible for proposing an independent set of experiments to study a given material that will test their mastery of experimental equipment, procedures, and associated data analysis. In addition, students will develop professional skills surrounding preparing professional technical reports and presentations in a team setting.

Fall
Prerequisite: MSE 2010 AND MSE 2020 AND MSE 3600
Corequisite: MSE 3600
.5 Course Units

MSE 3300 Self-Assembly of Soft Materials
Soft matter is found in diverse applications including sports (helmets & cloths); food (chocolate, egg); consumer products (e.g., lotions and shampoo); and devices (displays, electronics). Whereas solids and liquids are typically hard and crystalline or soft and fluid, respectively, soft matter can exhibit both solid and liquid like behavior. In this class, we investigate the thermodynamic and dynamic principles common to soft matter as well as soft (weak) forces, self-assembly and phase behavior. Classes of matter include colloidal particles, polymers, liquid crystalline molecules, amphiphilic molecules, biomacromolecules/membranes, and food.

Fall
Also Offered As: BE 3300
Prerequisite: CHEM 1021 OR MSE 2200 OR BE 2200
1 Course Unit

MSE 3600 Structure at the Nanoscale
To understand the atomic arrangements of crystalline matter, this class focuses on crystallography, symmetry, and diffraction techniques. The first half focuses on learning how to describe the structure of crystalline matter through the basics of crystallography and symmetry by introducing two-dimensional symmetry operations, point, and plane groups; this knowledge is then extended into three-dimensions to arrive at an understanding of space lattices and space groups. The second half is concerned with applying this information to understand structures through various diffraction and microscopy techniques.

Fall
1 Course Unit

MSE 3930 Materials Selection
Throughout mankind’s history, materials have played a critical role in civilization and technology. The selection of materials has been based on availability and functionality. The rapid advances of materials technologies in the last 150 years, however, have made nearly all classes and forms of materials available, at a cost. These costs include the dollars and cents costs that typically accompany the use of stronger, lighter materials, but environmental costs are also important and significant. Therefore, in theory at least, materials selection can now proceed on a rational basis as an optimization process involving performance and costs - both financial and environmental. In this course, we will focus on structural applications where mechanical design is central. By the end of the course, the students can expect to acquire a level of engineering familiarity with a broad range of materials, and be prepared to undertake responsible material design projects in the future.

Prerequisite: Junior standing or approval of the instructor

Spring
Prerequisite: MSE 2200
1 Course Unit

MSE 4050 Mechanical Properties of Macro/Nanoscale Materials
The application of continuum and microstructural concepts to elasticity and plasticity and the mechanisms of plastic flow and fracture in metals, polymers and ceramics. Topics covered include elasticity, viscoelasticity, plasticity, crystal defects, strengthening, crystallographic effects, twinning, creep and fatigue. Emphasis will be on mathematical and physical understanding rather than problem solving.

Spring
Also Offered As: MEAM 4050
Prerequisite: MSE 2200 or MEAM 2100 OR MATH 2400
1 Course Unit
MSE 4300 Introduction to Polymers
Polymer is one of the most widely used materials in our daily life, from the rubber tires to clothes, from photoresists in chip manufacturing to flexible electronics and smart sensors, from Scotch tapes to artificial tissues. This course teaches entry-level knowledge in polymer synthesis, characterization, thermodynamics, and structure-property relationship. Emphasis will be on understanding both chemical and physical aspects of polymers, polymer chain size and molecular interactions that drive the microscopic and macroscopic structures and the resulting physical properties. We will discuss how to apply polymer designs to advance nanotechnology, electronics, energy and biotechnology. Case studies include thermodynamics of block copolymer thin films and their applications in nanolithography, shape memory polymers, hydrogels, and elastomeric deformation and applications.
Fall
Also Offered As: CBE 4300
Prerequisite: (MSE 2600 OR CBE 2310) AND CHEM 2210 AND MEAM 2030
1 Course Unit

MSE 4400 Phase Transformations
The phase of a material is dependent upon temperature, thermal history, and other variables such as pressure and composition. In this course concepts of metallurgical thermodynamics and kinetics are used to study phase transformations to produce materials with desired properties. Subjects covered include diffusion in solids, crystal interfaces (coherent, semi-coherent, incoherent interfaces), nucleation and growth, equilibrium and nonequilibrium solidification processes, solid state transformations (nucleation and growth of precipitates, GP-Zone formation, Ostwald's step rule, order-disorder transition, spinodal decomposition, martensitic transformation).
Spring
Mutually Exclusive: MSE 5400
Prerequisite: MSE 2200 AND MSE 2600
1 Course Unit

MSE 4550 Electrochemical Engineering of Materials
After introducing basic electrochemical concepts including cell potential and cell thermodynamics, electrochemical kinetics, mass transport and cell overpotentials, redox reactions, electrolytic versus galvanic cells, standard reduction potentials, and key reactions in electrochemical energy conversion and storage, this course will cover the broad impact of electrochemical phenomena on materials. Topics that will be discussed include: (1) materials for lithium-ion battery electrodes, (2) materials extraction from their ores to finished products using electrochemical methods, (3) materials degradation by electrochemical corrosion, (4) Three-dimensional nanostructured materials by selective electrochemical corrosion. Students will be engaged in interactive classroom activities and hands-on electrochemical experiments (this year —fall 2022 — students will learn to cycle LiMn2O4 coin cell batteries).
Fall
Mutually Exclusive: MSE 5550
1 Course Unit

MSE 4600 Computational Materials Science
This course provides an introduction to modeling and simulation in materials science, covering continuum methods (e.g. finite element methods) and atomistic and molecular simulation (e.g. molecular dynamics). These tools play an increasingly important role in modern engineering. You will get hands-on training in both the fundamentals and applications of these methods to key engineering problems. The lectures will provide an exposure to areas of application, based on the scientific exploitation of the power of computation. We will use software packages (Comsol and LAMMPS) and thus extensive programming skills are not required. Matlab background needed for the course will be covered in a self-contained module. Junior or Senior Standing. Ability to write simple computer codes would be an advantage.
Fall
1 Course Unit

MSE 4650 Fabrication and Characterization of Micro and Nanostructured Materials
This course surveys various processes that are used to produce materials structured at the micron and nanometer scales for electronic, optical and biological applications. Basic principles of materials chemistry, physics, thermodynamics and surface/interfacial science are applied to solid state, liquid, and colloidal approaches to making materials. A wide range of nano- and microfabrication techniques, including photolithography, soft lithography, nanoimprint lithography, 3D printing and self-assembly, are covered. The course is heavily lab based, with 30% of class time and 50% of the homework devoted to hands on experiences and lab report writing. Lab assignments are a series of structured individual/group projects. Evaluation is based on 3 lab reports, 4 problem sets with journal paper reading assignment, and a final project design.
Spring
Mutually Exclusive: MSE 5650
1 Course Unit

MSE 4950 Senior Design
The senior design course is a two-semester capstone program that gives students the opportunity to design and execute an original experimental or theoretical project in materials science, engineering, or product/device development that is solving a real world problem. Students will work closely with a scientific advisor in their lab and meet once a week in the classroom to learn from an innovative curriculum that will build real-world skills in the context of their research and design project. These skills include project management, networking, teamwork, impactful written and verbal communications, upward management, self-reflection and feedback. Students will also learn how to design research in the context of having an impact on the world. This will be through weekly vignettes of innovative materials science solutions that solve problems in industries ranging from construction to healthcare to consumer products.
Fall
1 Course Unit
MSE 4960 Senior Design
The senior design course is a two-semester capstone program that gives students the opportunity to design and execute an original experimental or theoretical project in materials science, engineering, or product/device development that is solving a real world problem. Students will work closely with a scientific advisor in their lab and meet once a week in the classroom to learn from an innovative curriculum that will build real-world skills in the context of their research and design project. These skills include project management, networking, teamwork, impactful written and verbal communications, upward management, self-reflection and feedback. Students will also learn how to design research in the context of having an impact on the world. This will be through weekly vignettes of innovative materials science solutions that solve problems in industries ranging from construction to healthcare to consumer products.
Spring
1 Course Unit

MSE 5000 Experimental Methods in Materials Science
This laboratory course introduces students to a variety of experimental methods used in materials science and engineering. Hands-on training will be provided for atomic force microscopy, X-ray diffraction and scattering, mechanical testing with image capture, and dynamic light scattering. Students will use numerous software packages for data collection and analysis, as well as being introduced to LabVIEW as a method for customizing experiments. In addition, students will see demonstrations of scanning electron microscopy, transmission electron microscopy, and electron diffraction and analyze data from these methods. The format for the course will include a weekly lecture (1.5 hours), a weekly lab session (4 hours) and six assignments. Prerequisite: Permission of the Undergraduate Curriculum Chair and Instructor
Fall
1 Course Unit

MSE 5050 Mechanical Properties of Macro/Nanoscale Materials
The application of continuum and microstructural concepts to elasticity and plasticity and the mechanisms of plastic flow and fracture in metals, polymers and ceramics. Topics covered include elasticity, viscoelasticity, plasticity, crystal defects, strengthening, crystallographic effects, twinning, creep and fatigue. Emphasis will be on mathematical and physical understanding rather than problem solving.
Spring
Also Offered As: MEAM 5050
Prerequisite: MSE 2200 OR MEAM 2100 OR MATH 2400
1 Course Unit

MSE 5060 Failure Analysis of Engineering Materials
This course will introduce students to the broad field of failure through hands-on real-life examples of specific failures. All engineering materials classes will be considered, including metals, polymers, elastomers, ceramics, and glasses. Emphasis will be placed on understanding how to actually analyze a failed component and understand the cause of failure. Several classes will be conducted by outside experts from places like the NTSB, FBI and OSHA.
Fall
Also Offered As: MEAM 5060
Prerequisite: MSE 2200 AND (MSE 3930 or MEAN 3540)
1 Course Unit

MSE 5070 Fundamentals of Materials
This course will provide a graduate level introduction to the science and engineering of materials. It is designed specifically to meet the needs of students who will be doing research that involves materials but who do not have an extensive background in the field. The focus is on fundamental aspects of materials science and will emphasize phenomena and how to describe them. The course assumes an undergraduate background in any area of physical/chemical science and undergraduate mathematics appropriate to this. The course will also be accessible to students of applied mathematics.
Fall
Also Offered As: MEAM 5070
1 Course Unit

MSE 5150 Mathematics for Materials Science
Fall
1 Course Unit

MSE 5200 Structure of Materials
Crystal structure and bonding. Symmetry: line, plane, point, and space groups. Symmetry considerations in structure-property relations. Physical optics, diffraction as Fourier transforms. Effects of size, shape, temperature and distortion on diffraction intensity. Diffraction of gas, liquid, fibers, and DNA. Diffuse scattering, order/disorder. Pair distribution function, inverse problem, small angle scattering. Radiation-matter interaction, scattering physics, atomic and electronic spectroscopy. Prerequisite: Permission of the Undergraduate Curriculum Chair and Instructor
Spring
1 Course Unit

MSE 5250 Nanoscale Science and Engineering
Overview of existing device and manufacturing technologies in microelectronics, optoelectronics, magnetic storage, Microsystems, and biotechnology. Overview of near- and long-term challenges facing those fields. Near- and long-term prospects of nanoscience and related technologies for the evolutionary suspension of current approaches, and for the development of revolutionary designs and applications. Prerequisite: If course requirement not met, permission of instructor required.
Fall
Also Offered As: ESE 5250
Prerequisite: ESE 2180 OR PHYS 1240
1 Course Unit
MSE 5300 Thermodynamics and Phase Equilibria
Fundamental elements of engineering thermodynamics, statistical thermodynamics, chemical thermodynamics and defect thermodynamics. Thermodynamic functions, stability, phase transitions, mixtures (gases, condensed matter, polymer solution), defects and interfaces. Phase diagrams and predominance diagrams. Applications to energy problems (engines, efficiency, power, electrochemical cells) and properties (Curie's law, rubber elasticity, specific heat, phonon/photon spectra, constitutive equations, equation of states). Prerequisite: Permission of the Undergraduate Curriculum Chair and instructor
Fall
1 Course Unit

MSE 5360 Electronic Properties of Materials
This course will introduce the physical principles underlying broad spectrum of electronic properties in the solid state. Starting with the band structure of solids, the course will give an overview of electronic, dielectric, magnetic, thermal and optical properties of materials. The treatment will use quantum mechanical and statistical mechanical concepts familiar to students at the undergraduate level. Commonly used theories and models will be introduced and their predictions will be compared with observations. Students who have taken MSE 221/MSE 260 and/or MSE 570/MSE 575 will benefit from this advanced introduction to material properties.
Spring
1 Course Unit

MSE 5370 Nanotribology
Engineering is progressing to ever smaller scales, enabling new technologies, materials, devices, and applications. This course will provide an introduction to nano-scale tribology and the critical role it plays in the developing areas of nanoscience and nanotechnology. We will discuss how contact, adhesion, friction, lubrication, and wear at interfaces originate, using an integrated approach that combines concepts of mechanics, materials science, chemistry, and physics. We will cover a range of concepts and applications, drawing connections to both established and new approaches. We will discuss the limits of continuum mechanics and present newly developed theories and experiments tailored to describe micro- and nano-scale phenomena. We will emphasize specific applications throughout the course. Reading of scientific literature, critical peer discussion, individual and team problem assignments, and a peer-reviewed literature research project will be assigned as part of the course. Prerequisite: Freshman physics or consent of instructor.
Not Offered Every Year
Also Offered As: MEAM 5370
Prerequisite: MEAM 3540
1 Course Unit

MSE 5400 Phase Transformations
The phase of a material is dependent upon temperature, thermal history, and other variables such as pressure and composition. In this course concepts of metallurgical thermodynamics and kinetics are used to study phase transformations to produce materials with desired properties. Subjects covered include diffusion in solids, crystal interfaces (coherent, semi-coherent, incoherent interfaces), nucleation and growth, equilibrium and nonequilibrium solidification processes, solid state transformations (nucleation and growth of precipitates, GP-Zone formation, Ostwald's step rule, order-disorder transition, spinodal decomposition, martensitic transformation).
Spring
Mutually Exclusive: MSE 4400
1 Course Unit

MSE 5450 Materials for Energy and Environmental Sustainability
This course will cover the fundamental materials science issues central to the design of sustainable energy technology. The goal of this course is to expose students to the emerging advances in materials science and materials chemistry that underpin technologies for energy conversion (fuel cells, thermoelectrics, photovoltaics, wind energy etc.), storage (biofuels, artificial photosynthesis, batteries etc) and distribution (smart grids and hydrogen and methane economy concepts etc.) and to place these in a real world context. This class will emphasize concepts in "green materials and green engineering practices" that are emerging with a global focus on "Sustainable Technology." "Sustainability is defined as meeting the needs of the present without compromising the ability of future generations to meet their needs." Engineering materials and processes at all scales; molecular/nanometer, micro, and the macro-scale are critical to developing the tools society required to meet the growing needs for energy and sustainable materials for the built environment. This course is appropriate for graduate students and advanced undergraduates in Penn's Material Science Programs. Core MSE curriculum components in thermodynamics, structure, electronic & ionic transport, mechanics, polymers and optical materials will be expected, and exposure to the preparation in basic Chemistry and Physics will be advantageous in this highly interdisciplinary course.
Fall
1 Course Unit

MSE 5500 Elasticity and Micromechanics of Materials
This course is targeted to engineering students working in the areas on micro/nanomechanics of materials. The course will start with a quick review of the equations of linear elasticity and proceed to solutions of specific problems such as the Hertz contact problem, Eshelby's problem etc. Failure mechanisms such as fracture and the fundamentals of dislocations/plasticity will also be discussed. Prerequisite: graduate standing or permission of the instructor.
Fall
Also Offered As: MEAM 5190
Prerequisite: MEAM 5100
1 Course Unit

MSE 5550 Electrochemical Engineering of Materials
After introducing basic electrochemical concepts including cell potential and cell thermodynamics, electrochemical kinetics, mass transport and cell overpotentials, redox reactions, electrolytic versus galvanic cells, standard reduction potentials, and key reactions in electrochemical energy conversion and storage, this course will cover the broad impact of electrochemical phenomena on materials. Topics that will be discussed include: (1) materials for lithium-ion battery electrodes, (2) materials extraction from their ores to finished products using electrochemical methods, (3) materials degradation by electrochemical corrosion, (4) Three-dimensional nanostructured materials by selective electrochemical corrosion. Students will be engaged in interactive classroom activities and hands-on electrochemical experiments (this year —fall 2022 — students will learn to cycle LiMn2O4 coin cell batteries).
Fall
Mutually Exclusive: MSE 4550
1 Course Unit
MSE 5610 Atomic Modeling in Materials Science
This course covers two major aspects of atomic level computer modeling in materials. 1. Methods: Molecular statics, Molecular dynamics, Monte Carlo, Kinetic Monte Carlo as well as methods of analysis of the results such as radial distribution function, thermodynamics deduced from the molecular dynamics, fluctuations, correlations and autocorrelations. 2. Semi-empirical descriptions of atomic interactions: pair potentials, embedded atom method, covalent bonding, ionic bonding. Basics of the density functional theory. Mechanics, condensed matter physics, thermodynamics and statistical mechanics needed in interpretations are briefly explained. Prerequisite: Ability to write a basic code in a computer language such as fortran, C, C++
Spring
Also Offered As: MEAM 5530
1 Course Unit

MSE 5650 Fabrication and Characterization of Micro and Nanostructured Materials
This course surveys various processes that are used to produce materials structured at the micron and nanometer scales for electronic, optical and biological applications. Basic principles of materials chemistry, physics, thermodynamics and surface/interfacial science are applied to solid state, liquid, and colloidal approaches to making materials. A wide range of nano- and microfabrication techniques, including photolithography, soft lithography, nanoimprint lithography, 3D printing and self-assembly, are covered. The course is heavily lab based, with 30% of class time and 50% of the homework devoted to hands on experiences and lab report writing. Lab assignments are a series of structured individual/group projects. Evaluation is based on 3 lab reports, 4 problem sets with journal paper reading assignment, and a final project design. Prerequisite: If course requirement not met, permission of instructor required.
Spring
Mutually Exclusive: MSE 4650
Prerequisite: MSE 3600
1 Course Unit

MSE 5700 Physics of Materials I
Failures of classical physics and the historical basis for quantum theory. Postulates of wave mechanics; uncertainty principle, wave packets and wave-particle duality. Schrodinger equation and operators; eigenvalue problems in 1 and 3 dimensions (barriers, wells, hydrogen, atom). Perturbation theory; scattering of particles and light. Use of computer-aided self-study will be made. Undergraduate physics and math through modern physics and differential equations
Fall
1 Course Unit

MSE 5750 Statistical Mechanics
Statistical Mechanics is a unique branch of physics that permeates our understanding of matter at all length scales, from nanometers to stellar dimensions, and ranging in temperatures from pico-Kelvin (or lower) to billions of degrees Kelvin. This course will provide an overview of select topics in equilibrium and non-equilibrium statistical mechanics. The course will introduce the basic postulates of classical and quantum equilibrium statistical mechanics, explain the methodology of calculating observable properties, and discuss several applications in diverse fields. The second part of the course will introduce the methodology of non-equilibrium processes and discussing important theorems and results in the linear response regime. Finally, a brief discussion of systems far from equilibrium will be presented. Select applications from condensed matter physics, chemistry, materials science, biology, astrophysics, economics and meteorology will be used to illustrate the fundamental principles.
Spring
1 Course Unit

MSE 5760 Machine Learning and Its Applications in Materials Science
This graduate level course will introduce the basic methodology of machine learning (ML) and deep learning (DL) models and their applications to Materials Science and Engineering (MSE). The relationship between statistical mechanics based models and the evolution of ML and DL algorithms will be highlighted. There has been unprecedented growth of ML and DL models to predict and replace the time-consuming traditional pathway of discerning the synthesis-structure-property-performance relationship in materials. The free availability and exponential growth of databases containing materials structure, property, interatomic force fields and vast amounts of image processing data collected in high-resolution transmission electron microscopy, scanning probes and other tools used in microstructure characterization and quantification has enabled this rapid growth. This course will help students comprehend the following: (a) the connection between statistical mechanics and ML, DL modeling; (b) how to extract meaningful data from MSE databases both when the high quality training data is plentiful and also when it is scarce; (c) explore the interpretability and limitations of ML and DL model predictions due to a causal relationship between the input and the output that can impact the scientific outcome. The course emphasizes readings of scientific literature discussing ML applications in Materials Science, critical discussions, practice with ML and DL model algorithms using data libraries to reproduce existing results, and a term paper on a research project specific to materials structure-property-processing-defects-image analysis treated by DL methods.
Summer Term
Prerequisite: MSE 2600 AND MATH 2400
1 Course Unit
MSE 5800 Introduction to Polymers
Polymer is one of the most widely used materials in our daily life, from the rubber tires to clothes, from photoresists in chip manufacturing to flexible electronics and smart sensors, from Scotch tapes to artificial tissues. This course teaches entry-level knowledge in polymer synthesis, characterization, thermodynamics, and structure-property relationship. Emphasis will be on understanding both chemical and physical aspects of polymers, polymer chain size and molecular interactions that drive the microscopic and macroscopic structures and the resulting physical properties. We will discuss how to apply polymer designs to advance nanotechnology, electronics, energy and biotechnology. Case studies include thermodynamics of block copolymer thin films and their applications in nanolithography, shape memory polymers, hydrogels, and elastomeric deformation and applications.

Fall
Also Offered As: CBE 5100
1 Course Unit

MSE 5970 Master's Thesis Research
For students working on an advanced research leading to the completion of a Master's thesis.
Fall or Spring
1-2 Course Units

MSE 5990 Master's Indep Study
Fall or Spring
1-4 Course Units

MSE 6100 Transmission Electron Microscopy
Theory and application of transmission electron microscopy methods to problems in materials science and engineering, condensed matter physics, soft matter, polymeric materials, inorganic chemistry and chemical engineering. The principles of microscope operation, electron scattering, image formation and spectroscopy will be described, with an emphasis on both theory and experiment. With laboratory.
Not Offered Every Year
1 Course Unit

MSE 6110 Advanced Synchrotron and Electron Characterization of Materials
This course provides an overview of the latest techniques for the characterization of materials with synchrotron x-rays and electron microscopy. Emphasis is placed on understanding of x-ray and electron interactions with matter, and how these may be exploited to characterize structure and chemistry at the nanometer to atomic scale. Prerequisite: Graduate students: Background in solid-state physics, crystallography and quantum mechanics is strongly recommended. Undergraduates: MSE 570.
1 Course Unit

MSE 6400 Optical Materials
This course discusses the optical properties of modern materials engineered for specific functionality and covers exciting new developments being made in this rapidly evolving field. Emphasis is placed on how modern nanotechnology reshapes the light-matter interaction and delivers novel optical properties that are not available in nature.
Spring
1 Course Unit

MSE 6500 Mechanics of Soft and Biomaterials
This course is aimed to expose the students to a variety of topics in mechanic materials via discussion of “classic” problems that have had the widest impact long period of time and have been applied to analyze the mechanical behavior a variety of biological and engineering materials. Not Offered Every Year
Also Offered As: MEAM 6500
1 Course Unit

MSE 6990 MSE Seminar
The seminar course has been established so that students receive encouragement to attend and recognition for attending departmental seminars. Students registered for this course are required to attend weekly departmental seminars given by distinguished speakers from around the world. To obtain a satisfactory (S) grade, the student must attend more than 85% of such seminars. No unexcused absence allowed. Participation in the seminar course will be documented and recorded on the transcript. In order to obtain their degrees, doctoral students will be required to accumulate seven seminar courses and MS candidates two courses. Under special circumstances, i.e., in case of conflict with another course, the student may petition to the Graduate Group Chair to waive the seminar requirement for a particular semester.
1 Course Unit

MSE 7900 Selected Topics in Materials Science and Engineering
Students should check department office for special topics.
Fall or Spring
1 Course Unit

MSE 8950 Teaching Practicum
Fall or Spring
1 Course Unit