MATERIALS SCIENCE & ENGINEERING (MAT_SCI)

MAT_SCI 314-0 Thermodynamics of Materials (1 Unit)
Classical and statistical thermodynamics; entropy and energy functions in liquid and solid solutions, and their applications to phase equilibria. Lectures, problem solving. Materials science and engineering degree candidates may not receive credit for 314 with or after CHEM 342-1.
Prerequisite: CHEM 132-0, CHEM 152-0, CHEM 172-0 or CHEM 1X2; MATH 228-1 or MATH 230-1; or PHYSICS 135-1 or equivalent.

MAT_SCI 315-0 Phase Equilibria & Diffusion of Materials (1 Unit)
Application of thermodynamics to ternary phase equilibria. Defects and diffusion in solids. Interdiffusion. Short-circuit diffusion. Defects and transport in ionic solids. Lectures, problem solving, and laboratory.
Prerequisite: MAT_SCI 201-0 or MAT_SCI 301-0 or equivalent and MAT_SCI 314-0 or equivalent.

MAT_SCI 316-1 Microstructural Dynamics (1 Unit)
Principles underlying development of microstructures. Defects, diffusion, phase transformations, nucleation and growth, thermal and mechanical treatment of materials. Lectures, laboratory.
Prerequisite: MAT_SCI 315-0 or equivalent.

MAT_SCI 316-2 Microstructural Dynamics (1 Unit)
Principles underlying development of microstructures. Defects, diffusion, phase transformations, nucleation and growth, thermal and mechanical treatment of materials. Lectures, laboratory.
Prerequisite: MAT_SCI 316-1 or instructor consent.

MAT_SCI 318-0 Materials Selection (1 Unit)
Methods of specifying materials and the processes for making them in the context of a given application. Service performance of materials based on their physical and chemical properties. Case studies and use of high-level databases.
Prerequisite: MAT_SCI 201-0 or equivalent.

MAT_SCI 331-0 Soft Materials (1 Unit)
Different kinds of polymeric materials. Relationships between structure and physical properties; rubber elasticity, the glassy state, crystallinity in polymers. Lectures, laboratory.
Prerequisites: MAT_SCI 301-0 or equivalent; MAT_SCI 314-0 or CHEM 342-1; MAT_SCI 316-1 and MAT_SCI 316-2 highly recommended.

MAT_SCI 332-0 Mechanical Behavior of Solids (1 Unit)
Plastic deformation and fracture of metals, ceramics, and polymeric materials; structure/property relations. Role of imperfections, state of stress, temperatures, strain rate. Lectures, laboratory.
Prerequisites: MAT_SCI 316-1; MAT_SCI 316-2 (may be taken concurrently); CIV_ENV 216-0 or consent of instructor.

MAT_SCI 336-0 Synthetic Design of New Materials (1 Unit)
The design of new materials targeting important technological functions through processes requiring chemical reactions, synthesis of molecules, and molecular design for self-assembly and 3D printing. Fundamental principles and design strategies, including polymerization, biosynthesis and biocompatibility, design of molecular precursors for electronic materials and ceramics, synthesis of nanomaterials, composite and hierarchical structures.
Prerequisite: junior standing in materials science and engineering or consent of instructor.

MAT_SCI 340-0 Ceramic Processing (1 Unit)
Steps in production of fired ceramic articles. Powder preparation and characterization, compact formation, slip casting, extrusion and injection molding; firing, liquid-phase and solid-state sintering. Lectures, laboratory.
Prerequisite: MAT_SCI 316-1 or equivalent.

MAT_SCI 351-1 Introductory Physics of Materials (1 Unit)
Quantum mechanics; applications to materials and engineering. Band structures and cohesive energy; thermal behavior; electrical conduction; semiconductors; amorphous semiconductors; magnetic behavior of materials; liquid crystals. Lectures, laboratory, problem solving.
Prerequisites: MAT_SCI 301-0 or equivalent or consent of instructor; GEN_ENG 205-4 or equivalent; PHYSICS 135-2, PHYSICS 135-3; MAT_SCI 351-1 is prerequisite for MAT_SCI 351-2.

MAT_SCI 351-2 Introductory Physics of Materials (1 Unit)
Quantum mechanics; applications to materials and engineering. Band structures and cohesive energy; thermal behavior; electrical conduction; semiconductors; amorphous semiconductors; magnetic behavior of materials; liquid crystals. Lectures, laboratory, problem solving.
Prerequisites: MAT_SCI 301-0 or equivalent or consent of instructor; GEN_ENG 205-4 or equivalent; PHYSICS 135-2, PHYSICS 135-3; MAT_SCI 351-1 is prerequisite for MAT_SCI 351-2.

MAT_SCI 353-0 Bioelectronics (1 Unit)
Development and design of sensors, stimulators, and their medical devices for biointegrated electronics. Materials design and fabrication of passive and active components for sensitive, multimodal, and robust wearable and implantable devices.

MAT_SCI 354-0 Bioelectronics Lab (1 Unit)
Laboratories focused on the practical implementation, instrumentation, and fabrication of wearables and skinsensing. Applications range from vital sign monitoring to rehabilitation.
Prerequisites: BMD_ENG 353 or MAT_SCI 353. Concurrent enrollment is acceptable.

MAT_SCI 355-0 Electronic Materials (1 Unit)
Principles, models, and characterization of semiconductor materials. Crystal growth and doping. Diffusion, epitaxy, and monolithic processes. Current transport, non-equilibrium processes, thin films, low-mobility materials, and interfaces.
Prerequisite: MAT_SCI 316-1 or consent of instructor.

MAT_SCI 357-0 Nanomagnetic Materials for Information Storage (1 Unit)
Overview of materials used for magnetic data storage and of the recording and read processes. Information storage systems, such as optical, solid-state, and probe. Theoretical background for understanding the four energy terms that control the properties of magnetic materials when they are patterned at the nanoscale.

MAT_SCI 358-0 Modeling and Simulation in Materials Science and Engineering (1 Unit)
The course covers the essential methods and principles for modeling and simulating the structure, properties, and behavior of materials. It focuses on constructing models and identifying approaches to test either theoretical descriptions or experimental observations of materials phenomena on a computer. The course balances breadth versus depth of topics with the goal of producing researchers literate in computational materials science and its applicability across different length scales. Students will construct structure-property models of atomic assemblies, molecules, and solids using first-principles electronic structure (such as density-functional theory), deterministic (molecular dynamics), statistical methods (Monte Carlo and (Un)Supervised Learning), and finite elements models. Computational laboratories will give students extensive hands-on experience with several powerful modern materials modeling codes.

Prerequisite: MAT_SCI 314-0, MAT_SCI 315-0, MAT_SCI 316-1, and MAT_SCI 351-1.

MAT_SCI 360-0 Introduction to Electron Microscopy (1 Unit)
Theories and practice involved in application of scanning electron microscopy and transmission electron microscopy. Lectures, laboratory. Primarily for undergraduates and for graduate students in other departments.
Prerequisites: MAT_SCI 301-0; PHYSICS 135-2, PHYSICS 135-3 or equivalent.

MAT_SCI 361-0 Crystallography & Diffraction (1 Unit)
Elementary crystallography. Basic diffraction theory; reciprocal space. Applications to structure analysis, preferred orientation. Film and counter techniques. Lectures, laboratory.
Prerequisites: GEN_ENG 205-4 or equivalent; PHYSICS 135-2, PHYSICS 135-3.

MAT_SCI 371-0 Biominerals: Hierarchical Architecture & Function (1 Unit)
How biologically based processing of mineralorganic composites used by living organisms inspires new approaches to materials synthesis in many critical applications-locomotion (bones), defense (shells), and sensing (light, acceleration, magnetic fields).
Prerequisite: MAT_SCI 316-2 or equivalent, or consent of instructor.

MAT_SCI 376-0 Nanomaterials (1 Unit)
Introduction to structure-property relationships of materials processed at the nanometer scale. Highly interdisciplinary course appropriate for undergraduate and graduate students in other departments.
Prerequisite: MAT_SCI 351-1 or consent of instructor.

MAT_SCI 380-0 Intro Surface Science & Spectroscopy (1 Unit)
Surface spectroscopy, including Auger spectroscopy, photoemission, and LEED. Surface dynamics and thermodynamics. Electronic properties of surfaces and interfaces. Gas-surface interactions.
Prerequisite: MAT_SCI 351-1 or equivalent.

MAT_SCI 381-0 Materials for Energy-Efficient Technology (1 Unit)
A materials science approach to the challenges of energy efficient technology: energy content of materials; advanced materials for energy harvesting, transmission, storage, and conversion; materials for energy efficient transportation and housing. Term paper and oral presentation.
Prerequisite: MAT_SCI 201-0, MAT_SCI 301-0, or consent of instructor.

MAT_SCI 382-0 Electrochemical Energy Materials and Devices (1 Unit)
Thermodynamics and kinetics of electrochemical processes. Materials for fuel cells, batteries, and electrochemical capacitors, including electrolytes and electrodes. Electrical and mass transport. Effect of microstructure. Electrochemical characterization. Device configurations.
Prerequisite: senior standing or consent of instructor.

MAT_SCI 390-0 Materials Design (1 Unit)
Analysis and control of microstructures. Quantitative process/structure/property/performance relations, with case studies. Computer lab for modeling multicomponent thermodynamics and transformation kinetics.
Prerequisites: MAT_SCI 315-0, MAT_SCI 316-1, MAT_SCI 316-2, or consent of instructor.

MAT_SCI 391-0 Process Design (1 Unit)
Processing of materials. Design and analysis of experiments to identify and optimize key parameters to control properties and performance. Resolving conflicting requirements. Statistical process control.
Prerequisite: MAT_SCI 201 or 301 or faculty consent.

MAT_SCI 395-0 Special Topics in Materials Science and Engineering (1 Unit)
Topics suggested by students or faculty and approved by the department.

MAT_SCI 397-0 Special Topics in Materials Science and Engineering (0.34 Unit)
Special Topics in Materials Science and Engineering; laboratory emphasis.

MAT_SCI 401-0 Chemical & Statistical Thermodynamics of Materials (1 Unit)
Chemical thermodynamics via analytical and statistical approaches, including chemical potentials, conditions for equilibrium, distribution functions, ideal and regular solutions, and phase diagrams. Graduate core course.

MAT_SCI 402-0 Structure of Crystalline and Noncrystalline Materials (1 Unit)
Descriptors of material structure for crystalline and noncrystalline materials. Constitutive relationships described by tensors of rank 1 to 4. Classes of materials. Graduate core course.

MAT_SCI 404-1 Fundamentals of Soft Matter (0.5 Unit)
While certain properties of crystalline materials can be understood in terms of their periodic structure, many others derive from the disruptions to perfect periodicity. This course covers the (i) nature of imperfections in crystalline materials, covering point, line, and planar defects, (ii) strategies for controlling the concentration and types of defects, and (iii) the mechanisms by which defects control material behavior. Particular attention is paid to the role of point defects in mass and charge.

MAT_SCI 404-2 Imperfections in Materials (0.5 Unit)
This course describes assembly mechanisms that lead to soft materials of interests including amphiphilic assemblies in various topologies, molecular electrolytes in bulk and at interfaces, polymer blends and solutions, colloids and nanoparticles in suspensions and in aggregates, and biological and biomimetic gels.

MAT_SCI 405-0 Physics of Solids (1 Unit)
Reciprocal lattice representation, diffraction, Brillouin zone construction, bonding, lattice vibrations, phonon dispersion, and energy band structure of solids. Graduate core course.

MAT_SCI 406-0 Mechanical Properties of Materials (1 Unit)
Stress and strain tensors, piezoelectricity, elasticity, low- and high-temperature deformation of crystalline and non-crystalline materials, fatigue, and fracture. Graduate core course.

MAT_SCI 408-0 Phase Transformations in Materials (1 Unit)
Surfaces and interfaces, thermodynamics of phase transformations, nucleation, growth of precipitates, coarsening, and spinodal decomposition. Graduate core course.

MAT_SCI 411-0 Phase Transformations in Crystalline Materials (1 Unit)
Advanced treatment of order-disorder transformations, spinodal ordering, effects of stress on transformations, and displacive transformations.

MAT_SCI 415-0 Fundamentals of Thin Film Materials (1 Unit)
Vapor-phase film deposition techniques, adsorption, nucleation mechanisms, selective deposition, structure-zone diagrams, epitaxy, and composition.

MAT_SCI 416-0 Kinetics (1 Unit)
Principles of Irreversible Thermodynamics; Driving Forces and Fluxes; Diffusion in the Presence of Stress; Diffusion Resulting from other Gradients; Diffusion Resulting from Discrete Jumps; Diffusion in Crystals; Diffusion Controlled versus Source/Sink Controlled Kinetics; Surface Rearrangements by Evaporation and Condensation; Coarsening of Microstructures due to Capillary Forces; Growth of Phases in Concentration Gradients; Growth of Phases in Thermal Gradients; Evaporation of Metal Crystals; Vapor-Liquid-Solid (VLS) Growth Mechanism of the Growth of Nanowires.

MAT_SCI 431-0 Physical Chemistry of Polymers (1 Unit)
Introductory topics in macromolecular structures and conformation, polymer solution thermodynamics, linear viscoelasticity, rubber elasticity, and thermodynamics and kinetics of polymer phase transitions. Basic introduction to dynamics of polymer chains in solutions and melts and how it affects polymer manufacturing and processing. The course explores structure-property-processing relationships in polymeric materials along with the associated soft matter characterization techniques, broader themes that arise pertain to the large-scale applications of polymeric materials, the history of their development, and their environmental and societal impact.

MAT_SCI 432-0 Mechanics of Soft Matter (1 Unit)
A course on the mechanical properties of soft materials, designed for first year graduate students in Materials Science and related disciplines. Not recommended for students who have already taken MatSCI 332. Topics include matrix and tensor representations of stress and strain, including extensions to large strains, contact mechanics, fracture mechanics, yield, deformation and time dependent behavior. Applications of these concepts to polymeric materials is emphasized. Course notes (still under development) are available at msecore.northwestern.edu/495/495text.pdf.

MAT_SCI 435-0 High Temperature Materials (1 Unit)
Current research fields such as environmental effects on mechanical behavior at elevated temperatures, advanced instrumentation, advanced techniques, and surface interactions.

MAT_SCI 444-0 Organic Nanomaterials (1 Unit)
The materials science and chemistry of soft nanomaterials for myriad applications including nanomedicine. Preparative and synthetic approaches to organized, assembled, discrete nanomaterials will be described. Course will include an in depth discussion of advanced characterization techniques and strategies for this class of material.

MAT_SCI 445-0 Special Topics in Advanced Polymer Science (1 Unit)
Topics include application of statistical mechanics, morphology and crystallinity, spectroscopy, flow theory and molecular motion, and statistical theories of polymer composition and structure.

MAT_SCI 451-0 Advanced Physics of Materials (1 Unit)
Energy bands in solids, electronic conduction processes, dielectric properties, optical properties, semiconductors, magnetism, superconductivity, artificial structures, and amorphous materials.

MAT_SCI 452-0 Advanced Topics in the Solid State (1 Unit)
Topics include electrical and optical properties of solids, magnetic properties, theory of solids, and phase transformations.

MAT_SCI 453-0 Charge Transport in Electronic Materials (1 Unit)
Key models of electron and ion transport in hard and soft, crystalline and non-crystalline materials, including hopping, tunneling, polaronic transport and mixed conduction. Characterization methods including multi-point resistivity, impedance and noise spectroscopy, photoexcitation-based methods. Group-based learning from assigned papers in primary literature, supplemental lecture/discussion based on student constructed concept maps, independent project proposing extension to frontier materials.

MAT_SCI 456-0 Optical Properties of Materials (1 Unit)
Fundamentals of optical properties of materials. Beginning from Maxwell's equations and constitutive relations, covers common models used in the description of the optical constants of metals and insulators. Physics of absorption and scattering from small metallic and dielectric particles. A large portion of the course is on the design and physics of light-guiding structures, (micro-)nano-structured and subwavelength materials, periodic structures (photonic crystals), and photonic circuits. The course is focused on applications of these systems spanning communications to sensing and may introduce simulation software to design them.

MAT_SCI 458-0 Atomic Scale Computational Materials Science (1 Unit)
Theory and application of atomic-scale computational materials tools to model, understand, and predict the properties of real materials.

MAT_SCI 459-0 Materials Informatics (1 Unit)
The use of machine learning, artificial intelligence and data-driven tools applied to problems in materials science. Topics include materials informatics workflow; materials databases; materials representations based on features, structural information, and graph-based methods; feature engineering; materials applications of deep learning methods. Prerequisites: Some knowledge of python and basic familiarity with machine learning methods will be helpful.

MAT_SCI 460-0 Electron Microscopy (1 Unit)
Electron optics. Kinematic and dynamical theory of electron diffraction. Introduction to microanalysis.

MAT_SCI 461-0 Diffraction Methods in Material Science (1 Unit)
Advanced theory of diffraction. Diffraction effects accompanying imperfections. Thermal motion, cold-work, formation of solid solutions, transformations, liquids, gases, dynamic scattering.

MAT_SCI 465-0 Advanced Electron Microscopy & Diffraction (1 Unit)
Theories of electron diffraction; theories of diffraction contrast and their application to lattice disorder; phase transformation. Current topics in electron and other charged-particle microscopy.

MAT_SCI 466-0 Analytical Electron Microscopy (1 Unit)
Diversity of analytical techniques in modern TEM, fundamental concepts in quantitative x-ray, EELS, CBED microanalysis, advanced AEM instrumentation, techniques and applications to physical and life sciences.

MAT_SCI 471-0 Biominerals: Hierarchical Architecture and Function (1 Unit)
How biologically based processing of mineralorganic composites used by living organisms inspires new approaches to materials synthesis in many critical applications-locomotion (bones), defense (shells), and sensing (light, acceleration, magnetic fields).

MAT_SCI 483-0 Electrochemistry for Energy Storage and Conversion (1 Unit)
This course will focus on Thermodynamics and kinetics of ion and electron transport in solids, with emphasis on processes in electrolyte and electrode materials used in energy storage and conversion. Treatment of electroanalytical characterization techniques including a.c. impedance spectroscopy, voltammetry and d.c. polarization methods. Application areas include fuel cells, electrochemical gas separation membranes, batteries, supercapacitors, and hydrogen storage materials.

MAT_SCI 485-0 Electronic and Thermal Properties of Materials (1 Unit)
Solid-state electronic structure from a solid-sate chemistry perspective.

MAT_SCI 495-0 Advanced Special Topics in Material Science (1 Unit)
Topics suggested by students or faculty and approved by the department.

MAT_SCI 499-0 Projects (1 Unit)
Individual problems, including library or experimental work with a comprehensive report on some specific phase of materials science. PERMISSIONS OF INSTRUCTOR AND DEPARTMENT REQUIRED.

MAT_SCI 510-0 Special Topics (1 Unit)
Topics may be suggested by students or faculty, with the approval of the department.

MAT_SCI 590-0 Research (1-4 Units)

SEE DEPT FOR SECTION AND PERMISSION NUMBERS - Independent investigation of selected problems pertaining to thesis or dissertation. May be repeated for credit.

MAT_SCI 596-0 MS Thesis Research (1 Unit)
Research corresponding to MS thesis work for BS/MS students.