Department of Materials Science and Engineering

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Since the beginning of history, materials have played a crucial role in the growth, prosperity, security, and quality of human life. In fact, materials have been so intimately related to the emergence of human culture and civilization that anthropologists and historians have identified early cultures by the name of the significant materials dominating those cultures. These include the stone, bronze, and iron ages of the past. At the present time, the scope of materials science and engineering has become very diverse; it is no longer confined to topics related to metals and alloys but includes those relevant to ceramics, composites, polymers, biomaterials, nanostructures, intelligent materials, and electronic devices. In addition, present activities in materials science and engineering cover not only areas whose utility can be identified today, but also areas whose utility may be unforeseen. The services of materials scientists and engineers are required in a variety of engineering operations dealing, for example, with emerging energy systems, design of semiconductors and optoelectronic and nano devices, development of new technologies based on composites and high-temperature superconductivity, biomedical products, performance (e.g., quality, reliability, safety, energy efficiency) in automobile and aircraft components, improvement in nondestructive testing techniques, corrosion behavior in refineries, radiation damage in nuclear power plants, and fabrication of advanced materials.

Materials Science and Engineering focuses on the discovery of new materials, the tailoring of materials systems for optimum performance in a given technological application, and the design of novel materials solutions for emerging technologies. MSE is an interdisciplinary field incorporating elements of chemistry, physics, biology and/or engineering to derive and control the connections between structure (at length scales ranging from subatomic to macroscale), the processing necessary to achieve that structure, the fundamental properties (electrical, optical, thermal, mechanical, etc.), and their performance. These correlations are investigated using advanced materials characterization techniques and theoretical/computational analysis. Many of the most pressing scientific and technological challenges faced by humanity are constrained by the limits of currently available materials. The discovery, design and development of enabling materials is at the core of solving current and future scientific and engineering grand challenges, and benefit industries involved in electronics, advanced sensors, communications, human health, transportation, manufacturing recreation, energy conversion and storage, and environmental sustainability.

The Department of Materials Science and Engineering offers the B.S. in Materials Science and Engineering, a minor in Materials Science and Engineering, and the M.S. and Ph.D. in Materials Science and Engineering.

- Materials Science and Engineering, B.S.
- Materials Science and Engineering, M.S.
- Materials Science and Engineering, Minor
- Materials Science and Engineering, Ph.D.

Faculty

Diran Apelian, Sc.D. Massachusetts Institute of Technology, *Distinguished Professor of Materials Science and Engineering* (solidification processing; aluminum metallurgy; clean metal/melt refining; plasma processing/spray forming; powder metallurgy; nanostructured materials; semi-solid processing; thermal processing; resource recovery and recycling; innovation in engineering education)

William Bowman, Ph.D. Arizona State University, *Assistant Professor of Materials Science and Engineering* (materials for energy conversion and storage, advanced transmission electron microscopy and spectroscopy, correlating multiscale properties, electrical properties of ceramics, electrochemistry and defect chemistry, interfaces, grain boundaries and surfaces, electron energy-loss spectroscopy, ceramic processing and thin-film growth)

Ty Christoff-Tempesta, Ph.D. Massachusetts Institute of Technology, *Assistant Professor of Materials Science and Engineering* (Molecular design, polymer chemistry, small-molecule self-assembly, macromolecular architectures, soft matter dynamics, bio-inspired materials, sustainability and health)

Stacy Copp, Ph.D. University of California, Santa Barbara, *Assistant Professor of Materials Science and Engineering; Physics and Astronomy* (soft matter-based photonic materials; metal nanoclusters; polymer nanostructures; self-assembly; biomimetics; machine learning for materials discovery)

Shen Dillon, Ph.D. Lehigh University, *Professor of Materials Science and Engineering* (materials processing, advanced and in situ characterization, materials for extreme environments, materials in energy storage and conversion systems, grain boundary and interface science)

James Earthman, Ph.D. Stanford University, *Professor of Materials Science and Engineering; Biomedical Engineering* (biomaterials, compositionally complex materials, nanocrystalline alloys, quantitative percussion diagnostics, deformation and damage processes)

Kai He, Ph.D. Arizona State University, *Department Graduate Advisor for Continuing Students and Associate Professor of Materials Science and Engineering* (transmission electron microscopy, spectroscopy, and holography; nanoscale phenomena and multifunctional materials; batteries, fuel cells, and catalysts for clean energy, quantum materials and devices)

Allon Hochbaum, Ph.D. University of California, Berkeley, *Associate Professor of Materials Science and Engineering; Chemical and Biomolecular Engineering; Chemistry; Molecular Biology and Biochemistry* (biological materials, protein materials, electronic conductivity in proteins, materials and methods to study microbes and microbial communities)

David Kisailus, Ph.D. University of California, Santa Barbara, *Henry Samueli Faculty Excellence Professor of Materials Science and Engineering* (investigation of synthesis - structure and structure - property relationships in biological and biomimetic materials, development of multifunctional structural materials, synthesis and crystal growth of nanoscale materials for energy conversion, storage, and environmental remediation)

Enrique Lavernia, Ph.D. Massachusetts Institute of Technology, *Distinguished Professor Emeritus of Materials Science and Engineering* (nanostructured materials, additive manufacturing, powder metallurgy, light weight metals and composites, mechanical behavior, high entropy metals)

Elizabeth M. Y. Lee, Ph.D. Massachusetts Institute of Technology, *Samueli Faculty Development Chair and Assistant Professor of Materials Science and Engineering; Chemical and Biomolecular Engineering* (computational materials and chemistry; quantum, electronic and energy materials; nanoscale transport phenomena; machine learning)

Martha L. Mecartney, Ph.D. Stanford University, *Professor Emerita of Materials Science and Engineering* (ceramics for energy applications and for extreme environments, flash sintering, interfacial design of thermal conductivity, transmission electron microscopy)

Farghalli A. Mohamed, Ph.D. University of California, Berkeley, *Professor Emeritus of Materials Science and Engineering* (mechanical behavior of engineering materials such as metals, composites and ceramics, the correlation between behavior and microstructure, creep and superplasticity, mechanisms responsible for strengthening and fracture)

Daniel R. Mumm, Ph.D. Northwestern University, *Professor of Materials Science and Engineering* (materials for extreme environments, power generation and propulsion systems, inorganics for energy conversion and storage, coatings for thermal/environmental protection, additive manufacturing, materials degradation, and advanced materials characterization via electron microscopy, spectroscopy, and diffraction analysis)

Xiaoqing Pan, Ph.D. Saarlandes University, *Henry Samueli Endowed Chair and Director of Irvine Materials Research Institute (IMRI) and Distinguished Professor of Materials Science and Engineering; Chemical and Biomolecular Engineering; Physics and Astronomy* (atomic-scale structure, properties and dynamic behaviors of advanced materials including thin films and nanostructures for memories, catalysts, and energy conversion and storage devices)

Regina Ragan, Ph.D. California Institute of Technology, *Professor of Materials Science and Engineering; Chemical and Biomolecular Engineering* (self-assembly, nanophotonic sensors for medical diagnostics and environmental monitoring, machine learning analysis of spectral data)

Julie M. Schoenung, Ph.D. Massachusetts Institute of Technology, *Co-Director of the World Institute of Sustainable Development of Materials (WISDOM) and Distinguished Professor Emerita of Materials Science and Engineering* (sustainable development of materials, materials processing and characterization, nanostructured materials, structure-property, relationships, additive manufacturing, high entropy ceramics)

Matthew Sheldon, Ph.D. University of California, Berkeley, *Associate Professor of Chemistry; Materials Science and Engineering; Materials Science and Engineering* (analytical and materials chemistry)

Qi Song, Ph.D. Fudan University, *Assistant Professor of Materials Science and Engineering* (discovery of Low-dimensional quantum materials through atomic-scale synthesis, spectroscopy characterization, and device development leveraging interface states and emergent quantum effects)

Lorenzo Valdevit, Ph.D. Princeton University, *Department Chair and Director of Institute for Design and Manufacturing Innovation (IDMI) and Professor of Materials Science and Engineering; Mechanical and Aerospace Engineering* (architected materials, mechanical metamaterials, additive manufacturing, optimal design)

Affiliate Faculty

Mohammad Javad Abdolhosseini Qomi, Ph.D. Massachusetts Institute of Technology, *Associate Professor of Civil and Environmental Engineering; Materials Science and Engineering* (mechanics and physics of multi-scale porous materials, interfacial phenomena, cement chemistry, geochemistry)

Tayloria Adams, Ph.D. Michigan Technological University, *Assistant Professor of Chemical and Biomolecular Engineering; Anatomy and Neurobiology; Biomedical Engineering; Materials Science and Engineering* (dielectrophoresis, microfluidic devices, stem cells, biomarker development, cell membrane biophysics, cell sorting)

Shane Ardo, Ph.D. Johns Hopkins University, *Professor of Chemistry; Chemical and Biomolecular Engineering; Materials Science and Engineering* (inorganic and organometallic, physical chemistry and chemical physics, polymer, materials, nanoscience)

Peter J. Burke, Ph.D. Yale University, *Professor of Electrical Engineering and Computer Science; Biomedical Engineering; Materials Science and Engineering* (nano-electronics, bio-nanotechnology)

Penghui Cao, Ph.D. Boston University, *Associate Professor of Mechanical and Aerospace Engineering; Materials Science and Engineering* (fundamental understanding of the mechanisms by which materials plasticly deform and fail, particularly in extreme environments)

Sarah C. Finkeldei, Ph.D. RWTH Aachen University, *Assistant Professor of Chemistry; Chemical and Biomolecular Engineering; Materials Science and Engineering* (nuclear chemistry)

Alon A. Gorodetsky, Ph.D. California Institute of Technology, *Associate Professor of Molecular Biology and Biochemistry; Materials Science and Engineering* (cephalopods, adaptive materials, camouflage, bioelectronics)

Jered Haun, Ph.D. University of Pennsylvania, *Associate Professor of Biomedical Engineering; Chemical and Biomolecular Engineering; Materials Science and Engineering* (nanotechnology, molecular engineering, computational simulations, targeted drug delivery, clinical cancer detection)

Matthew Law, Ph.D. University of California, Berkeley, *Professor of Chemistry; Chemical and Biomolecular Engineering; Materials Science and Engineering* (inorganic and organometallic, physical chemistry and chemical physics, polymer, materials, nanoscience)

Mo Li, Ph.D. University of Michigan, *Department Chair and Professor of Civil and Environmental Engineering; Materials Science and Engineering* (novel infrastructure materials and advanced manufacturing methods, and their interfaces with structural engineering, sensing and health monitoring, energy and environment)

Ray Luo, Ph.D. University of Maryland, College Park, *Professor of Molecular Biology and Biochemistry; Biomedical Engineering; Chemical and Biomolecular Engineering; Materials Science and Engineering* (protein structure, noncovalent associations involving proteins)

Ali Mohraz, Ph.D. University of Michigan, *Professor of Chemical and Biomolecular Engineering; Materials Science and Engineering* (colloid science, soft matter engineering with applications in health care and energy materials)

SungWoo Nam, Ph.D. Harvard University, *Professor of Mechanical and Aerospace Engineering; Materials Science and Engineering* (Materials, mechanics and multifunctionality; understanding mechanically coupled properties in low-dimensional materials; building devices based on advanced materials)

Joseph Patterson, Ph.D. University of Warwick, *Professor of Chemistry; Materials Science and Engineering* (polymer, materials, nanoscience)

Maxim Shcherbakov, Ph.D. Lomonosov Moscow State University, *Assistant Professor of Electrical Engineering and Computer Science; Materials Science and Engineering* (nanophotonics, nonlinear and quantum optics, nanofabrication, strong-#eld physics, ultrafast processes)

Matthew Sheldon, Ph.D. University of California, Berkeley, *Associate Professor of Chemistry; Materials Science and Engineering; Materials Science and Engineering* (analytical and materials chemistry)

Quinton Smith, Ph.D. John Hopkins University, *Assistant Professor of Chemical and Biomolecular Engineering; Biomedical Engineering; Materials Science and Engineering* (pluripotent stem cells, regenerative medicine, organoids, microfluidics, tissue engineering)

Vasan Venugopalan, Sc.D. Massachusetts Institute of Technology, *Department Chair and Professor of Chemical and Biomolecular Engineering; Biomedical Engineering; Materials Science and Engineering; Mechanical and Aerospace Engineering; Surgery* (laser-generated thermal, mechanical and radiative transport processes for application in medical diagnostics, imaging, therapeutics, biotechnology)

Xizheng Wang, Ph.D. University of Maryland, College Park, *Assistant Professor of Mechanical and Aerospace Engineering; Materials Science and Engineering* (Sustainable electrified synthesis and manufacturing of functional nano/bulk materials, electrified additive manufacturing, in-situ characterizations under extreme thermal conditions)

Yoon Jin Won, Ph.D. Stanford University, *Associate Professor of Mechanical and Aerospace Engineering; Electrical Engineering and Computer Science; Materials Science and Engineering* (multi-scale structures for thermal and energy applications, in particular fabrication, characterization, and integration of structured materials)

Huolin Xin, Ph.D. Cornell University, *Professor of Physics and Astronomy; Materials Science and Engineering*

Iryna Zenyuk, Ph.D. Carnegie Mellon University, *Director of National Fuel Cell Research Center and Professor of Chemical and Biomolecular Engineering; Materials Science and Engineering; Mechanical and Aerospace Engineering* (renewable energy, fuel cells, electrolyzers, batteries, X-ray imaging techniques, multi-scale modeling, transport phenomena)

Courses

MSE 45. Materials in Art and Archaeology. 4 Units.
An exploration of the materials science of art and archaeological artifacts. From paints and pigments to ceramics and metals, examines how materials structure and properties have been exploited and engineered throughout history for artistic expression.
(II)

MSE 48. Edible Materials: Lab to Table. 4 Units.
Explores concepts of materials science and engineering through food. Structure-property-processing-performance relationships are examined in discussions and demonstrations to relate sensory experiences of edible materials with materials science principles.
(II and Va)

MSE 60. Laboratory in Synthesis and Characterization of Materials. 4 Units.
Synthesis and characterization of ceramic, polymer, and semiconductor materials. Connect the process, structure, properties, and performance to materials science knowledge in a hands-on laboratory setting. Materials Fee
Prerequisite: ENGR 54 and CHEM 1C.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 69. Electronic and Optical Properties in Materials. 4 Units.
Covers the electronic, optical, and dielectric properties of crystalline and amorphous materials to provide a foundation of the underlying physical principles governing the properties of existing and emerging electronic and photonic materials.
Prerequisite: PHYSICS 7D and PHYSICS 7E and (MATH 3A or I&C SCI 6N) and MATH 3D and ENGR 54.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 141. Nano-Scale Materials and Applications. 4 Units.
Overview of the chemistry, physics, and applications of nanometer-scale materials. Explore the effects of composition, bonding, and confinement on physical properties of nanomaterials, their chemical syntheses, and their device physics in electronic, optoelectronic, and energy technologies.
Prerequisite: (ENGR 1A or CHEM 1A or CHEM H2A) and ENGR 54 and MSE 69.
Restrictions: Biomedical Engineering majors, Chemical Engineering majors, and Materials Science and Engineering majors have the first consideration for enrollment.
Concurrent: MSE 241

MSE 142. Synthesis and Properties of Biological, Biomimetic, and Bio-Inspired Materials. 4 Units.
Synthesis of biological materials, including self-assembly and biomineralization, and translational processing to engineered materials via additive manufacturing, freeze casting, and other methods. Subsequent functional properties of these materials are reviewed.
Prerequisite: ENGR 54 and MSE 165C.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 151. Polymeric Materials. 4 Units.
An introduction to physical aspects of polymers, including polymer molecular size and configuration, solution and bulk phase structural properties, mechanical properties including viscoelasticity and rheology, polymer synthesis methods, characterization techniques, processing methods, and examples from existing and emerging polymeric materials.
Prerequisite: ENGR 54 and (MSE 165A or CBE 40C or ENGRMAE 91).
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 155. Mechanical Behavior and Design Principles. 4 Units.
Principles governing structure and mechanical behavior of materials, relationship relating microstructure and mechanical response with application to elasticity, plasticity, yielding, necking, creep, and fracture of materials. Introduction to experimental techniques to characterize the properties of materials. Design parameters.
Prerequisite: ENGR 54.
Same as ENGRMAE 156
Restrictions: Mechanical Engineering majors and Materials Science and Engineering majors have the first consideration for enrollment. Aerospace Engineering majors have second consideration for enrollment.

MSE 155L. Mechanical Behavior Laboratory. 2 Units.
Introduction to experimental techniques to characterize mechanical properties of materials. Emphasis on correlations between property and microstructure. Experiments include: plastic stability in tension, effect of grain size on flow stress, microstructural engineering. Materials Fee
Corequisite: MSE 155.
Prerequisite: ENGR 54.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 158. Ceramic Materials for Sustainable Energy. 4 Units.
A technical elective for students interested in materials. Topics covered include structure and properties of ceramic materials, and design for sustainable energy applications.
Prerequisite: ENGR 54.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment. Chemical Engineering majors have second consideration for enrollment.

MSE 163. Computer Techniques in Experimental Research. 4 Units.
Principles and practical guidelines of automated materials testing. Computer fundamentals, programming languages, data acquisition and control hardware, interfacint techniques, programming strategies, data analysis, data storage, safeguard procedures.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment. Chemical Engineering majors have second consideration for enrollment.

MSE 164. X-ray Diffraction, Electron Microscopy, and Microanalysis. 4 Units.
Material characterization using X-ray diffraction and scanning electron microscopy (SEM). Topics include X-ray diffraction and analysis; SEM imaging and microanalysis.
Prerequisite: ENGR 54 and PHYSICS 7D.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 164L. X-ray Diffraction, Electron Microscopy, and Microanalysis Lab. 1 Unit.
Material characterization using X-ray diffraction and scanning electron microscopy (SEM). Topics include X-ray diffraction and analysis; SEM imaging and microanalysis. Materials Fee
Prerequisite: ENGR 54 and PHYSICS 7D.
Restrictions: Materials Science and Engineering majors only.

MSE 165A. Thermodynamics of Materials. 4 Units.
Treatment of the laws of thermodynamics and their application in understanding properties and equilibrium states of engineering materials. Develops relationships pertaining to multiphase equilibrium and presents graphical constructions for interpretation of phase diagrams. Statistical thermodynamics in relation to materials phenomena.
Prerequisite: CHEM 1C and PHYSICS 7C.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 165B. Diffusion and Heat Transport in Materials. 4 Units.
Examines how kinetics affect materials development, behavior, and processing. Highlights the ways in which kinetics and diffusion are key to designing materials processing and heat treating strategies, with examples in various applied topics.
Prerequisite: ENGR 54 with a minimum grade of C- and (MSE 165A with a minimum grade of C- or CBE 40C or ENGRMAE 91).
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 165C. Materials Kinetics and Phase Transformations. 4 Units.
Treatment of the kinetics of solid-state reactions and reactions at interfaces. Thermodynamics and kinetics of phase transformations, including solidification processes, diffusional and diffusionless phase transformations.
Prerequisite: ENGR 54 and (MSE 165A with a minimum grade of C- or CBE 40C or ENGRMAE 91) and (MSE 165B or BME 150 or ENGRMAE 120 or (CBE 120B and CBE 120C)).
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 165CL. Laboratory in Materials Kinetics and Phase Transformations. 2 Units.
Covers topics of practical application of the kinetics of solid state reactions, reactions at interfaces, and the thermodynamics and kinetics of phase transformations to common materials systems.
Prerequisite: ENGR 54 and (MSE 165B with a minimum grade of C- or (CBE 120B and CBE 120C) or ENGRMAE 120).
Restrictions: Materials Science and Engineering majors only.

MSE 171. Green Engineering: Theory and Practice. 4 Units.
Methods and impacts of selecting alternative technologies, processes, materials, chemicals, to reduce pollution, waste, and use of toxic substances, thereby creating "green," environmentally responsible, sustainable solutions. Topics include environmental regulations, recycling, life-cycle assessment, economic analysis, design, green chemistry, and toxicology.
Restrictions: Seniors and Materials Science and Engineering majors have the first consideration for enrollment.

MSE 174. Composite Materials Design. 4 Units.
Introduction to fiber-reinforced composites for mechanical applications. Properties of reinforcing fibers. Manufacture of fibers and composites. Micromechanics of fiber composites. Strength criteria and failure modes. Macromechanics in design of laminated composite structures.
Prerequisite: ENGR 54 and ENGR 150.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 175. Design Failure Investigation. 4 Units.
Survey of mechanisms by which devices fail, including overload, fatigue, corrosion, and wear. Use of fractography and other evidence to interpret failure modes and specify design/manufacturing changes. Students redesign failed parts or structures based on actual parts and/or case histories.
Prerequisite: ENGR 54.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment. Chemical Engineering majors have second consideration for enrollment.

MSE 176. Surface and Adhesion Science. 4 Units.
Structure, thermodynamics of, kinetics, and reactions on surfaces. Surface electronic and mechanical properties and characterization of all classes of materials including metals, semiconductors, ceramics, polymers, and soft materials. Adhesion between different materials is also addressed.
Prerequisite: (CBE 110 or MSE 165C) and (MSE 141 or MSE 69).
Same as CBE 183
Restrictions: Chemical Engineering majors and Materials Science and Engineering majors have the first consideration for enrollment.
Concurrent: MSE 276, CBE 283

MSE 178. Fundamentals of Materials Processing: How are Materials Processed to Make Things?. 4 Units.
In-depth knowledge of manufacturing processes (from liquid, solid, and vapor phases) with focus on the fundamentals of materials processing – transport and mechanical forces. Processing fundamentals that apply to the three main classes of engineering materials: metals, ceramics, and polymers.
Prerequisite: ENGR 54.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.
Concurrent: MSE 278

MSE 187. Essential Skills in Engineering. 4 Units.
A 10-week immersion in the essential skills that are the anchors for being a supreme professional. Designed with many case studies and complemented with appearances by successful industry leaders.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.
Concurrent: MSE 287

MSE 189A. Senior Design Project I. 3 Units.
Group supervised senior design projects that deal with materials selection in engineering design and that involve case studies in ethics, safety, design, failure modes, new products, and patents. Activities conclude with a presentation of the projects. Materials Fee
Prerequisite: ENGR 54 and MSE 155 and MSE 60 and MSE 165C.
Restrictions: Seniors and Materials Science and Engineering majors only. MSE 189A, MSE 189B, and MSE 189C must be taken in the same academic year.

MSE 189B. Senior Design Project II. 3 Units.
Group supervised senior design projects that deal with materials selection in engineering design and that involve case studies in ethics, safety, design, failure modes, new products, and patents. Activities conclude with a presentation of the projects. Materials Fee
Prerequisite: MSE 189A.
Restrictions: Seniors and Materials Science and Engineering majors only. MSE 189A, MSE 189B, and MSE 189C must be taken in the same academic year.

MSE 189C. Senior Design Project III. 3 Units.
Group supervised senior design projects that deal with materials selection in engineering design and that involve case studies in ethics, safety, design, failure modes, new products, and patents. Activities conclude with a presentation of the projects. Materials Fee
Prerequisite: MSE 189B.
Restrictions: Seniors and Materials Science and Engineering majors only. MSE 189A, MSE 189B, and MSE 189C must be taken in the same academic year.

MSE 190. Materials Selection and Design. 4 Units.
Meaning and phases of design; design considerations; properties of engineering materials; materials property charts; materials selection; process selection; multi-constraint and multi-objective design. Selection of shape in mechanical components. Designing with hybrid materials: challenges and opportunities. Environmental considerations; case studies.
Prerequisite: ENGR 54 and ENGR 150.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 191. Materials Outreach. 3 Units.
Demonstrates major concepts in Materials Science and Engineering. Concepts of materials engineering covered include deformation in crystalline solids, effects of heat treatment on mechanical properties, thermal barrier materials, composites design, mechanical behavior of polymers, superconductivity in ceramics.
Prerequisite: ENGR 54.
Restrictions: Materials Science and Engineering majors have the first consideration for enrollment.

MSE 195. Special Topics in Materials Science and Engineering. 1-4 Units.
Studies in selected areas of Materials Science and Engineering. Topics addressed vary each quarter.
Prerequisite: Prerequisites vary.
Repeatability: May be taken unlimited times as topics vary

MSE 197. Materials Science and Engineering Internship. 2-12 Units.
Students majoring in MSE may receive credit for an approved internship, working at a company under the supervision of an industry mentor and a faculty advisor. Enables students to gain valuable experience in a professional setting and enhance their skills.
Grading Option: Pass/Not Pass only
Repeatability: May be taken for credit 3 times

MSE 198. Group Study. 1-4 Units.
Group study of selected topics in engineering.
Repeatability: May be taken unlimited times

MSE 199. Individual Study. 1-4 Units.
Supervised independent reading, research, or design for undergraduate Engineering majors. Students taking individual study for design credit are to submit a written paper to the instructor and to the Undergraduate Student Affairs Office in the School of Engineering.
Repeatability: May be taken for credit for 8 units
Restrictions: Materials Science and Engineering majors only.

MSE 199P. Individual Study. 1-4 Units.
Supervised independent reading, research, or design for undergraduate Engineering majors. Students taking individual study for design credit are to submit a written paper to the instructor and to the Undergraduate Student Affairs Office in the School of Engineering.
Grading Option: Pass/Not Pass only
Repeatability: May be taken unlimited times

MSE 200. Structure of Materials. 4 Units.
Foundations and framework for understanding, quantifying and characterizing structure of crystalline and non-crystalline materials. Focuses on using mathematical and graphical descriptors of structural arrangement, symmetry, short/long-range order, tensors in real space and reciprocal space, fundamentals of diffraction-based materials analysis.
Prerequisite: Recommended: Graduate standing in Materials Science and Engineering, Chemical Engineering, or related educational background (physical sciences or engineering), along with an introductory course in materials science (E54 or equivalent).

MSE 201A. Critical Analysis and Technical Communication I. 2 Units.
Develop an understanding of the process to conduct research. Topics include performing analytical analysis of the scientific literature, formation of a hypothesis, defining investigations to validate hypothesis, communicating analysis in written form, writing a research proposal.

MSE 201B. Critical Analysis and Technical Communication II. 2 Units.
Develop oral presentation skills and skills to understand significance of published research. Topics include performing critical and analytical analysis of the scientific literature, connecting core course content with experimental/theoretical methods in the scientific literature, and communicating analysis in oral form.
Prerequisite: MSE 201A with a minimum grade of B-.

MSE 205. Materials Physics. 4 Units.
Covers the electronic, optical, and dielectric properties of crystalline materials to provide a foundation of the underlying physical principles of governing the properties of existing and emerging electronic and photonic materials.
Prerequisite: MSE 200 with a minimum grade of B-.

MSE 241. Nano-Scale Materials and Applications. 4 Units.
Overview of the chemistry, physics, and applications of nanometer-scale materials. Explore the effects of composition, bonding, and confinement on physical properties of nanomaterials, their chemical syntheses, and their device physics in electronic, optoelectronic, and energy technologies.
Prerequisite: MSE 200 with a minimum grade of B- and MSE 205 with a minimum grade of B-.
Concurrent: MSE 141

MSE 249. Special Topics in Materials Science and Engineering. 1-4 Units.
Studies in selected areas of Materials Science and Engineering. Topics addressed vary each quarter.
Prerequisite: Prerequisites vary.
Repeatability: May be taken unlimited times as topics vary

MSE 254. Polymer Science and Engineering. 4 Units.
An introduction to physical aspects of polymers, including configuration and conformation of polymer chains and characterization techniques; crystallinity visoelasticity, rheology, and processing.

MSE 255A. Design with Ceramic Materials. 4 Units.
Dependence of ceramic properties on bonding, crystal structure, defects, and microstructure. Ceramic manufacturing technology. Survey of physical properties. Strength, deformation, and fracture of ceramics. Mechanical design with brittle, environment-sensitive materials exhibiting time-dependent strengths.
Prerequisite: ENGR 54.

MSE 256A. Mechanical Behavior of Engineering Materials. 4 Units.
Principles governing structure and mechanical behavior of materials, relationship relating microstructure and mechanical response with application to elasticity, plasticity, creep, and fatigue, study of rate-controlling mechanisms and failure modes, fracture of materials.

MSE 256B. Fracture of Engineering Materials. 4 Units.
Fracture mechanics and its application to engineering materials. Elastic properties of cracks, the stress intensity factor, the crack tip plastic zone, the J integral approach, fracture toughness testing, the crack tip opening displacement, fracture at high temperatures, fatigue crack growth.

MSE 259. Transmission Electron Microscopy. 4 Units.
The theory and operation of the transmission electron microscope (TEM), including the basic construction, electron optics, electron diffraction and reciprocal space, formation of image and electron diffraction information, microanalysis, and specimen preparation.
Prerequisite: MSE 200 with a minimum grade of B-.

MSE 262. Grain Boundaries and Interfaces in Nanocrystalline Materials. 4 Units.
Structure and character of grain boundaries and interfaces in solids including nanocrystalline materials. Role of grain boundaries in chemical segregation, fracture, deformation, creep, conductivity, diffusion, and grain growth. Experimental techniques and computational methods used to characterize and model grain boundaries.
Prerequisite: MSE 200 with a minimum grade of B-.

MSE 264. Scanning Electron Microscopy. 4 Units.
The theory and operation of the scanning electron microscope (SEM) and X-ray microanalysis. Topics covered include the basic design and electron optics, electron beam - specimen interactions, image formation and interpretation, X-ray spectrometry, and other related topics and techniques.
Prerequisite: MSE 200 with a minimum grade of B-.

MSE 265A. Materials Thermodynamics and Statistical Mechanics. 4 Units.
Topics related to classical and statistical thermodynamics applied to materials science, including partition functions, energy, enthalpy, entropy, free energies, equilibrium, solutions and mixtures, phase diagrams.
Prerequisite: MSE 200 with a minimum grade of B-.

MSE 265B. Phase Transformations and Kinetic Phenomena in Materials. 4 Units.
Topics related to phase transitions in materials including treatments of diffusion, nucleation and growth, dynamics of diffusional and diffusion-less phase transitions, solidification, and capillarity driven kinetics.
Prerequisite: MSE 265A with a minimum grade of B-.

MSE 267. Seminar in Systems Microbiology Research. 1 Unit.
A research and journal club seminar that covers topics on bacteria and phage using approaches and principles from biology, engineering, and physics.
Same as PHYSICS 268, MOL BIO 268
Grading Option: Satisfactory/Unsatisfactory only
Repeatability: May be taken unlimited times

MSE 271. Green Engineering: Theory and Practice. 4 Units.
Methods and impacts of selecting alternative technologies, processes, materials, chemicals, to reduce pollution, waste, and use of toxic substances, thereby creating “green,” environmentally responsible, sustainable solutions. Topics include environmental regulations, recycling, life-cycle assessment, economic analysis, design, green chemistry, and toxicology.

MSE 273. Electroceramics Solid State Electrochemical Systems. 4 Units.
Theory, underlying principles, experimental techniques, and applications of electroceramics and solid-state electrochemical systems. Links solid state physics, atomic structure, thermodynamics, defect chemistry, and transport processes to electrical properties of ceramics - spanning from insulators to fast-ion conductors and HT superconductors.
Prerequisite: MSE 200 with a minimum grade of B-.

MSE 276. Surface and Adhesion Science. 4 Units.
Structure, thermodynamics of, kinetics, and reactions on surfaces. Surface electronic and mechanical properties and characterization of all classes of materials including metals, semiconductors, ceramics, polymers, and soft materials. Adhesion between different materials is also addressed.
Same as CBE 283
Concurrent: MSE 176, CBE 183

MSE 277. Material Resources, Recovery, and Reuse - Recycling. 4 Units.
Issues focusing on production waste, post-consumer waste, and design and manufacture for recyclability. Students learn fundamentals of extractive metallurgical processes; circular economy principles; understand the recovery and reuse issues for a variety of materials; proficiency in enabling technology for recycling.
Concurrent: MSE 177

MSE 278. Fundamentals of Materials Processing: How are Materials Processed to Make Things?. 4 Units.
In-depth knowledge of manufacturing processes (from liquid, solid, and vapor phases) with focus on the fundamentals of materials processing – transport and mechanical forces. Processing fundamentals that apply to the three main classes of engineering materials: metals, ceramics, and polymers.
Concurrent: MSE 178

MSE 287. Essential Skills in Engineering. 4 Units.
A 10-week immersion in the essential skills that are the anchors for being a supreme professional. Designed with many case studies and complemented with appearances by successful industry leaders.
Concurrent: MSE 187

MSE 295. Seminar in Engineering. 1-4 Units.
Seminars by individual faculty in major fields of interest.
Grading Option: Satisfactory/Unsatisfactory only
Repeatability: May be taken unlimited times as topics vary

MSE 296. Master of Science Thesis Research. 1-16 Units.
Individual research or investigation conducted in preparation for the thesis required for the M.S. degree in Engineering.
Repeatability: May be taken unlimited times

MSE 297. Doctor of Philosophy Dissertation Research. 1-16 Units.
Individual research or investigation conducted in preparation for the dissertation required for the Ph.D. degree in Engineering.
Repeatability: May be taken unlimited times

MSE 298. Seminars in Materials Science and Engineering. 2 Units.
Presentation of advanced topics and reports of current research efforts in Materials Science and Engineering.
Grading Option: Satisfactory/Unsatisfactory only
Repeatability: May be taken unlimited times

MSE 299. Individual Research. 1-16 Units.
Individual research or investigation under the direction of an individual faculty member.
Grading Option: Satisfactory/Unsatisfactory only
Repeatability: May be taken unlimited times