Materials Sciences and Engineering

**MSEN 5300 (PHYS 5376)** Introduction to Materials Science (3 semester hours) This course provides an intensive overview of materials science and engineering and includes the foundations required for further graduate study in the field. Topics include atomic structure, crystalline solids, defects, failure mechanisms, phase diagrams and transformations, metal alloys, ceramics, polymers as well as their thermal, electrical, magnetic and optical properties. (3-0) R

**MSEN 5310** Thermodynamics of Materials (3 semester hours) Work, energy and the first law of thermodynamics; the second law of thermodynamics, thermodynamic potentials, the third law of thermodynamics, thermodynamic identities and their uses, phase equilibria in one-component systems, behavior and reactions of gases. Solutions, binary and multicomponent systems: phase equilibria, materials separation and purification. Electrochemistry. Thermodynamics of modern materials. (3-0) S

**MSEN 5320** Materials Science for Sustainable Energy (3 semester hours) Sustainable energy solutions require examining current fossil fuel supply, climate change, and renewable energy source development. Fossil fuel supply and climate change are intimately related, and the global community is actively developing renewable energy source to replace the fossil fuel and minimize its impact on the climate change. Materials science will enable diverse renewable energy technologies (solar cell, biofuel, wind, geothermal etc.) and their practical utilization (energy storage, fuel cell, electrical vehicles, etc.). This course will examine energy and climate issues and sustainable energy solutions with emphasis on the role of materials science. (3-0) T

**MSEN 5331 (CHEM 5331)** Advanced Organic Chemistry I (3 semester hours) Modern concepts of bonding and structure in covalent compounds. Static and dynamic stereochemistry and methods for study. Relationships between structure and reactivity. Prerequisite: **CHEM 2325** or equivalent. (3-0) Y

**MSEN 5333 (CHEM 5333)** Advanced Organic Chemistry II (3 semester hours) Application of the principles introduced in **CHEM 5331**, emphasizing their use in correlating the large body of synthetic/preparative organic chemistry. Prerequisite: **MSEN 5331/CHEM 5331**. (3-0) R

**MSEN 5340 (CHEM 5340)** Advanced Polymer Science and Engineering (3 semester hours) Polymer structure-property relations, Linear and nonlinear viscoelasticity. Dynamic mechanical analysis, time-temperature superposition, creep and stress relaxation. Mechanical models for prediction of polymer deformation, rubber elasticity, environmental effects on polymer deformation, instrumentation for prediction of long term properties. (3-0) R

**MSEN 5341 (CHEM 5341)** Advanced Inorganic Chemistry I (3 semester hours) Physical inorganic chemistry addressing topics in structure and bonding, symmetry, acids and bases, coordination chemistry and spectroscopy. Prerequisite: **CHEM 3341** or consent of instructor. (3-0) Y

**MSEN 5344** Thermal Analysis (3 semester hours) Differential scanning calorimetry; thermogravimetric analysis; dynamic mechanical and thermomechanical analysis; glass transition; melting transitions, relaxations in the glassy state, liquid crystalline phase changes. Prerequisite: **MSEN 5360** or equivalent. (3-0) R
MSEN 5353 Integrated Circuit Packaging (3 semester hours) Basic packaging concepts, materials, fabrication, testing, and reliability, as well as the basics of electrical, thermal, and mechanical considerations as required for the design and manufacturing of microelectronics packaging. Current requirements and future trends will be presented. General review of analytical techniques used in the evaluation and failure analysis of microelectronic packages. Prerequisite: MSEN 6324. (3-0) R

MSEN 5355 (CHEM 5355) Analytical Techniques I (3 semester hours) Study of fundamental analytical techniques, including optical spectroscopic techniques, mass spectrometry, and microscopic and surface analysis methods. (3-0) Y

MSEN 5356 (CHEM 5356) Analytical Techniques II (3 semester hours) Study of chromatography (GC, LC, CZE), statistical methods (standard tests and ANOVA), chemical problem solving, and modern bio/analytical techniques such as biochips, microfluidics, and MALDI-MS. Prerequisite: CHEM 5355 or consent or instructor. (3-0) R

MSEN 5360 Materials Characterization (3 semester hours) Survey of atomic and structural analysis techniques as applied to surface and bulk materials. Physical processes involved in the interaction of ions, electrons and photons with solids; characteristics of the emergent radiation in relation to the structure and composition. Prerequisite: MSEN 5300. Prerequisite or corequisite: MSEN 6319 or equivalent. (3-0) S

MSEN 5361 Fundamentals of Surface and Thin Film Analysis (3 semester hours) Survey of materials characterization techniques; Rutherford backscattering; secondary ion mass spectroscopy; ion channeling; scanning tunneling and transmission microscopy; x-ray photoelectron and Auger electron spectroscopy; x-ray and electron diffraction. Prerequisite: MSEN 5360 or equivalent. (3-0) R

MSEN 5370 Ceramics and Metals (3 semester hours) Emphasis on structure-property relationships: chemical bonding, crystal structures, crystal chemistry, electrical properties, thermal behavior, defect chemistry. Chemical and physical properties of metals and alloys. Topics include: powder preparation, sol-gel synthesis, densification, toughening mechanisms, crystal structure, thermodynamics, phase diagrams, phase transformations, oxidation, mechanical, electrical and magnetic properties. Prerequisites: MSEN 5300 and 5310 or equivalents. (3-0) R

MSEN 5371 (PHYS 5371) Solid State Physics (3 semester hours) Symmetry description of crystals, bonding, properties of metals, electronic band theory, thermal properties, lattice vibration, elementary properties of semiconductors. Prerequisites: PHYS 5301 and 5320 or equivalent. (3-0) Y

MSEN 5375 Electronic Devices Based On Organic Solids (3 semester hours) Solid state device physics based on organic condensed matter structures, including: OLEDs (organic light emitting diodes), organic FETs, organic lasers, plastic photocells, molecular electronic chips. (3-0) R

MSEN 5377 (PHYS 5377) Computational Physics of Nanomaterials (3 semester hours) This course introduces atomistic and quantum simulation methods and their applications to modeling study nanomaterials (nanoparticles, nanowires, and thin films). The course has three main parts: basic theory of materials (thermodynamics, statistical mechanics, and solid state physics), computational methods to model materials systems, and applications to practical problems. There are three main themes of the course: structure-property relationship of nanomaterials; atomistic modeling for atomic structure optimization; and quantum simulations for electronic structure study and functional property analysis. Prerequisite: MSEN 6319 or equivalent. (3-0) R
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Description</th>
<th>Prerequisites</th>
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<tr>
<td>MSEN 5383</td>
<td>Plasma Technology</td>
<td>3</td>
<td>Hardware oriented study of useful laboratory plasmas. Topics will include vacuum technology, gas kinetic theory, basic plasma theory and an introduction to the uses of plasmas in various industries. (3-0) T</td>
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<tr>
<td>MSEN 5410</td>
<td>Biochemistry</td>
<td>4</td>
<td>Analysis of the structure and function of proteins and nucleic acids and of their interactions. Metabolic biochemistry, especially as it relates to disease states. Prerequisite: BIOL 3361 (biochemistry) or equivalent. (4-0) Y</td>
<td>BIOL 3361</td>
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<tr>
<td>MSEN 5440</td>
<td>Cell Biology</td>
<td>4</td>
<td>Molecular architecture and function of cells and subcellular organelles; structure and function of membranes; hormone and neurotransmitter action; growth regulation and oncogenes; immune response; eukaryotic gene expression. Prerequisites: BIOL 5410 and BIOL 5420, or the equivalent, or permission of the instructor. (4-0) Y</td>
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<tr>
<td>MSEN 6310</td>
<td>Mechanical Properties of Materials</td>
<td>3</td>
<td>Phenomenology of mechanical behavior of materials at the macroscopic level and the relationship of mechanical behavior to material structure and mechanisms of deformation and failure. Topics covered include elasticity, viscoelasticity, plasticity, creep, fracture, and fatigue. Prerequisite: MECH 3301 or MSEN 5300 or equivalent. (3-0) R</td>
<td>MECH 3301, MSEN 5300</td>
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<tr>
<td>MSEN 6313</td>
<td>Semiconductor Opto-Electronic Devices</td>
<td>3</td>
<td>Physical principles of semiconductor optoelectronic devices: optical properties of semiconductors, optical gain and absorption, wave guiding, laser oscillation in semiconductors, LEDs, physics of detectors, applications. Prerequisite: EE 3310 or equivalent. (3-0) R</td>
<td>EE 3310</td>
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<tr>
<td>MSEN 6319</td>
<td>Quantum Mechanics for Materials Scientists</td>
<td>3</td>
<td>Quantum-mechanical foundation for study of nanometer-scale materials. Principles of quantum physics, stationary-states for one-dimensional potentials, symmetry considerations, interaction with the electromagnetic radiation, scattering, reaction rate theory, spectroscopy, chemical bonding and molecular orbital theory, solids, perturbation theory, nuclear magnetic resonance. (3-0) S</td>
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<tr>
<td>MSEN 6320</td>
<td>Fundamentals of Semiconductor Devices</td>
<td>3</td>
<td>Semiconductor material properties, band structure, equilibrium carrier distributions, non-equilibrium current-transport processes, and recombination-generation processes. Prerequisite: EEMF 6319 or equivalent. (3-0) Y</td>
<td>EEMF 6319</td>
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<tr>
<td>MSEN 6321</td>
<td>Active Semiconductor Devices</td>
<td>3</td>
<td>The physics of operation of active devices will be examined, including p-n junctions, bipolar junction transistors and field-effect transistors: MOSFETs, JFETS, and MESFETS. Active two-terminal devices and optoelectronic devices will be presented. Recommended co-requisite: MSEN 6320. (3-0) Y</td>
<td>MSEN 6320</td>
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<tr>
<td>MSEN 6322</td>
<td>Semiconductor Processing Technology</td>
<td>3</td>
<td>Modern techniques for the manufacture of semiconductor devices and circuits. Techniques for both silicon and compound semiconductor processing are studied as well as an introduction to the design of experiments. Topics include: wafer growth, oxidation, diffusion, ion implantation, lithography, etch and deposition. (3-0) T</td>
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<tr>
<td>MSEN 6324</td>
<td>Electronic, Optical and Magnetic Materials</td>
<td>3</td>
<td>Foundations of materials properties for electronic, optical and magnetic applications. Electrical and thermal conduction, elementary quantum physics, modern theory of solids, semiconductors and devices, dielectrics, magnetic</td>
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and optical materials properties. Prerequisite: MSEN 5300 or equivalent. (3-0) T

**MSEN 6327** Semiconductor Device Characterization (3 semester hours) This course will describe the theoretical and practical considerations associated with the most common electrical and reliability characterization techniques used in the semiconductor industry. Prerequisite: (EE 6320 or MSEN 6320) or equivalent, or permission of instructor. (3-0) T

**MSEN 6330** Phase Transformations (3 semester hours) Thermodynamic, kinetic, and structural aspects of metallic and ceramic phase transformations: mechanisms and rate-determining factors in solid-phase reactions; diffusion processes, nucleation theory, precipitations from solid solution, order-disorder phenomena, and applications of binary and ternary phase diagrams. Prerequisite: MSEN 5310 or equivalent. (3-0) R

**MSEN 6339** Nanostructured Materials: Synthesis, Properties and Application (3 semester hours) Exploration of the synthesis, properties and applications of quantum dots, wells, rods, wires, particles and related nanostructures. The theoretical and experimental evidence for quantum-confinement effects, which are of considerable fundamental and applied interest, will be discussed. The manipulation of surface properties of nanostructures, their incorporation into bulk nanocomposites and their application to technological devices will be discussed. Prerequisites or corequisites: MSEN 5310 and MSEN 5360 and MSEN 6319 and MSEN 6324, or equivalent. (3-0) T

**MSEN 6340** Advanced Electron Microscopy (3 semester hours) Theory and applications of scanning and transmission electron microscopy; sample preparation, ion beam and analytical techniques. Prerequisite: MSEN 5360 or equivalent. (3-0) Y

**MSEN 6341** Advanced Electron Microscopy Laboratory (3 semester hours) Lab support for MSEN 6340. MSEN 6340 must be taken with or before MSEN 6341. (0-3) Y

**MSEN 6348** (EEMF 6348, MECH 6341) Lithography and Nanofabrication (3 semester hours) Study of the principles, practical considerations, and instrumentation of major lithography technologies for nanofabrication of devices and materials. Advanced photolithography, electron beam lithography, nanoimprint lithography, x-ray lithography, ion beam lithography, soft lithography, and scanning probe lithography, basic resist and polymer science, applications in nanoelectronic and biomaterials. (3-0) Y

**MSEN 6350** Imperfections in Solids (3 semester hours) Point defects in semiconductors, metals, ceramics, and nonideal defect structures; nonequilibrium conditions produced by irradiation or quenching; effects of defects on electrical and physical properties, effects of defects at interfaces between differing materials. Prerequisites: MSEN 5310 and MSEN 6324 or equivalents. (3-0) R

**MSEN 6355** (BMEN 6355) Nanotechnology and Sensors (3 semester hours) Introduction to the concept of nanotechnology, in context toward designing sensors/diagnostic devices. Identifying the impact of nanotechnology in designing "state-of-the art" sensors for healthcare applications. Topics include: nanotechnology and nanomaterials, principles of sensing and transduction and heterogeneous integration toward sensor design. (3-0) Y

**MSEN 6358** (BIOL 6358) Bionanotechnology (3 semester hours) Protein, nucleic acid and lipid structures. Macromolecules as structural and functional units of the intact cell. Parallels between biology and nanotechnology. Applications of nanotechnology to biological systems. (3-0) T
**MSEN 6361** Deformation Mechanisms in Solid Materials (3 semester hours) Linear elastic fracture mechanics, elastic-plastic fracture mechanics, time dependent failure, creep and fatigue, experimental analysis of fracture, fracture and failure of metals, ceramics, polymers and composites. Failure analysis related to material, product design, manufacturing and product application. Prerequisite: **MSEN 5300** or **MECH 6301/MSEN 6310** or equivalent. (3-0) R

**MSEN 6362** Diffraction Science (3 semester hours) Diffraction theory; scattering and diffraction experiments; kinematic theory; dynamical theory; x-ray topography; crystal structure analysis; disordered crystals; quasi-crystals. (3-0) R

**MSEN 6361 (PHYS 6371)** Advanced Solid State Physics (3 semester hours) Continuation of **MSEN 5371/PHYS 5371**, transport properties of semiconductors, ferroelectricity and structural phase transitions, magnetism, superconductivity, quantum devices, surfaces. Prerequisite: **MSEN 5371/PHYS 5371** or equivalent. (3-0) R

**MSEN 6374 (PHYS 6374)** Optical Properties of Solids (3 semester hours) Optical response in solids and its applications. Lorentz, Drude and quantum mechanical models for dielectric response function. Kramers-Kronig transformation and sum rules considered. Basic properties related to band structure effects, excitons and other excitations. Experimental techniques including reflectance, absorption, modulated reflectance, Raman scattering. Prerequisite: **MSEN 5371/PHYS 5371** or equivalent. (3-0) R


**MSEN 6382 (EEMF 6382, MECH 6347)** Introduction to MEMS (3 semester hours) Study of micro-electromechanical devices and systems and their applications. Microfabrication techniques and other emerging fabrication processes for MEMS are studied along with their process physics. Principles of operations of various MEMS devices such as mechanical, optical, thermal, magnetic, chemical/biological sensors/actuators are studied. Topics include: bulk/surface micromachining, LIGA, microsensors and microactuators in multiphysics domain. (3-0) T

**MSEN 7320 (EEMF 7320)** Advanced Semiconductor Device Theory (3 semester hours) Quantum mechanical description of fundamental semiconductor devices; carrier transport on the submicron scale; heterostructure devices; quantum-effect devices. Prerequisite: **EEMF 6320** and **EEMF 6321**. (3-0) R

**MSEN 7v80** Special Topics in Materials Science and Engineering (1-6 semester hours) For letter grade credit only. (May be repeated for a maximum of 9 hours.) ([1-6]-0) S

**MSEN 8v40** Individual Instruction in Materials Science and Engineering (1-6 semester hours) (May be repeated for credit.) For pass/fail credit only. ([1-6]-0) S

**MSEN 8v70** Research in Materials Science and Engineering (3-9 semester hours) (May be repeated for
credit.) For pass/fail credit only. ([3-9]-0) S

**MSEN 8v98** Thesis (3-9 semester hours) (May be repeated for credit.) For pass/fail credit only. ([3-9]-0) S

**MSEN 8v99** Dissertation (1-9 semester hours) (May be repeated for credit.) For pass/fail credit only. ([1-9]-0) S