MATERIALS SCIENCE & ENGINEER (MATSCI)

MATSCI 10. Materials Matter. 1 Unit.
All facets of engineering rely on materials to develop modern devices and solve the greatest technological challenges in society today. In this introductory 1-unit course, students will learn about the field of Materials Science and Engineering and its broad applications in research and industry. Students who are interested in careers in energy and sustainability, biomaterials and regenerative medicine, or engineering matter at the atomic scale for electronics and nanotechnology will be able to have an early window into the work done in these areas through this course. Each week, students will listen to talks from invited guest speakers and discover the wide variety of career opportunities and areas of focus offered through Materials Science and Engineering. Additionally, students will have the opportunity to develop networks with Stanford alumni and current students in our department. This course is open to all undergraduates and does not have any pre-requisites.

MATSCI 100. Undergraduate Independent Study. 1-3 Unit.
Independent study in materials science under supervision of a faculty member.

MATSCI 142. Quantum Mechanics of Nanoscale Materials. 4 Units.
Introduction to quantum mechanics and its application to the properties of materials. No prior background beyond a working knowledge of calculus and high school physics is presumed. Topics include: The Schrodinger equation and applications to understanding of the properties of quantum dots, semiconductor heterostructures, nanowires, and bulk solids. Tunneling processes and applications to nanoscale devices; the scanning tunneling microscope, and quantum cascade lasers. Simple models for the electronic properties and band structure of materials including semiconductors, insulators and metals and applications to semiconductor devices. Time-dependent perturbation theory and interaction of light with materials with applications to laser technology. Recommended: ENGR 50 or equivalent introductory materials science course. (Formerly 157).

MATSCI 143. Materials Structure and Characterization. 4 Units.
Students will study the theory and application of characterization techniques used to examine the structure of materials at the nanoscale. Students will learn to classify the structure of materials such as semiconductors, ceramics, metals, and nanotubes according to the principles of crystallography. Methods used widely in academic and industrial research, including X-ray diffraction and electron microscopy, will be demonstrated along with their application to the analysis of nanostructures. Prerequisites: E-50 or equivalent introductory materials science course. (Formerly 153).

MATSCI 144. Thermodynamic Evaluation of Green Energy Technologies. 4 Units.
Understand the thermodynamics and efficiency limits of modern green technologies such as carbon dioxide capture from air, fuel cells, batteries, and solar-thermal power. Recommended: ENGR 50 or equivalent introductory materials science course. (Formerly 154).

MATSCI 145. Kinetics of Materials Synthesis. 4 Units.
The science of synthesis of nanometer scale materials. Examples including solution phase synthesis of nanoparticles, the vapor-liquid-solid approach to growing nanowires, formation of mesoporous materials from block-copolymer solutions, and formation of photonic crystals. Relationship of the synthesis phenomena to the materials science driving forces and kinetic mechanisms. Materials science concepts including capillarity, Gibbs free energy, phase diagrams, and driving forces. Prerequisites: MatSci 144. (Formerly 155).

MATSCI 150. Undergraduate Research. 3-6 Units.
Participation in a research project.

MATSCI 151. Microstructure and Mechanical Properties. 3-4 Units.
Primarily for students without a materials background. Mechanical properties and their dependence on microstructure in a range of engineering materials. Elementary deformation and fracture concepts, strengthening and toughening strategies in metals and ceramics. Topics: dislocation theory, mechanisms of hardening and toughening, fracture, fatigue, and high-temperature creep. Undergraduates register in 151 for 4 units; graduates register for 251 in 3 units.
Same as: MATSCI 251

MATSCI 152. Electronic Materials Engineering. 4 Units.
Materials science and engineering for electronic device applications. Kinetic molecular theory and thermally activated processes; band structure; electrical conductivity of metals and semiconductors; intrinsic and extrinsic semiconductors; elementary p-n junction theory; operating principles of light emitting diodes, solar cells, thermoelectric coolers, and transistors. Semiconductor processing including crystal growth, ion implantation, thin film deposition, etching, lithography, and nanomaterials synthesis.

MATSCI 156. Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution. 3-4 Units.
Operating principles and applications of emerging technological solutions to the energy demands of the world. The scale of global energy usage and requirements for possible solutions. Basic physics and chemistry of solar cells, fuel cells, and batteries. Performance issues, including economics, from the ideal device to the installed system. The promise of materials research for providing next generation solutions. Undergraduates register in 156 for 4 units; graduates register in 256 for 3 units. Prerequisites: MATSCI 145 and 152 or equivalent coursework in thermodynamics and electronic properties.

MATSCI 158. Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life. 4 Units.
The relationships between molecular structure, morphology, and the unique physical, chemical, and mechanical behavior of polymers and other types of soft matter are discussed. Topics include methods for preparing synthetic polymers and examination of how enthalpy and entropy determine conformation, solubility, mechanical behavior, microphase separation, crystallinity, glass transitions, elasticity, and linear viscoelasticity. Case studies covering polymers in biomedical devices and microelectronics will be covered. Recommended: ENGR 50 and Chem 31A or equivalent.
Same as: BIOE 158

MATSCI 159Q. Japanese Companies and Japanese Society. 3 Units.
Preference to sophomores. The structure of a Japanese company from the point of view of Japanese society. Visiting researchers from Japanese companies give presentations on their research enterprise. The Japanese research ethic. The home campus equivalent of a Kyoto SCTI course.
Same as: ENGR 159Q

MATSCI 160. Nanomaterials Laboratory. 3-4 Units.
This course is designed for students interested in exploring the cutting edge of nanoscience and nanotechnology. Students will learn several fundamental concepts related to nanomaterials synthesis and characterization that are commonly used in research and industrial settings. Students will also investigate several applications of nanomaterials through a series of assessments, including self-assembled monolayers, nanowire photovoltaics, and nanoparticles for drug delivery and biomarker screening. In lieu of traditional labs, students will attend weekly discussion sections aimed at priming students to think like a materials engineer. Through these discussions, students will explore how to design an effective experiment, how to identify research gaps, and how to write an effective grant proposal. Enrollment limited to 24. Prerequisites: ENGR 50. Contact instructor for more details. Undergraduates register for 160 for 4 units, Graduates register for 170 for 3 units.
Same as: MATSCI 170

MATSCI 161. Energy Materials Laboratory. 3-4 Units.
From early church architecture through modern housing, windows are passages of energy and matter in the forms of light, sound and air. By letting in heat during the summer and releasing it in winter, windows can place huge demands on air conditioning and heating systems, thereby increasing energy consumption and raising greenhouse gas levels in the atmosphere. Latest advances in materials science have enabled precise and on-demand control of electromagnetic radiation through `smart¿ dynamic windows with photochromic and electrochromic materials that change color and optical density in response to light radiance and electrical potential. In this course, we will spend the whole quarter on a project to make and characterize dynamic windows based on one of the electrochromic material systems, the reversible electroplating of metal alloys. There will be an emphasis in this course on characterization methods such as scanning electron microscopy, x-ray photoelectron spectroscopy, optical spectroscopy, four-point probe measurements of conductivity and electrochemical measurements (cyclic voltammetry). The course will finish with students giving presentations on the prospects of using dynamic windows and generic radiation control in cars, homes, commercial buildings or airplanes. Undergraduates register for 161 for 4 units; graduates register for 171 for 3 units.
Same as: MATSCI 171

MATSCI 162. X-Ray Diffraction Laboratory. 3-4 Units.
Experimental x-ray diffraction techniques for microstructural analysis of materials, emphasizing powder and single-crystal techniques. Diffraction from epitaxial and polycrystalline thin films, multilayers, and amorphorous materials using medium and high resolution configurations. Determination of phase purity, crystallinity, relaxation, stress, and texture in the materials. Advanced experimental x-ray diffraction techniques: reciprocal lattice mapping, reflectivity, and grazing incidence diffraction. Enrollment limited to 20. Undergraduates register for 162 for 4 units; graduates register for 172 for 3 units. Prerequisites: MATSCI 143 or equivalent course in materials characterization.
Same as: MATSCI 172, PHOTON 172

MATSCI 163. Mechanical Behavior Laboratory. 3-4 Units.
Technologically relevant experimental techniques for the study of the mechanical behavior of engineering materials in bulk and thin film form, including tension testing, nanoindentation, and wafer curvature stress analysis. Metallic and polymeric systems. In addition to regularly scheduled lecture (M/W), this course includes a three-hour lab session every other week (T/W/Th). Register for lecture section in addition to one lab section. Undergraduates register for 163 in 4 units; graduates register in 173 for 3 units.
Same as: MATSCI 173

MATSCI 164. Electronic and Photonic Materials and Devices Laboratory. 3-4 Units.
Lab course. Current electronic and photonic materials and devices. Device physics and micro-fabrication techniques. Students design, fabricate, and perform physical characterization on the devices they have fabricated. Established techniques and materials such as photolithography, metal evaporation, and Si technology; and novel ones such as soft lithography and organic semiconductors. Prerequisite: MATSCI 152 or 199 or consent of instructor. Undergraduates register in 164 for 4 units; graduates register in 174 for 3 units. Students are required to sign up for lecture and one lab section.
Same as: MATSCI 174

MATSCI 165. Nanoscale Materials Physics Computation Laboratory. 3-4 Units.
Computational exploration of fundamental topics in materials science using Java-based computation and visualization tools. Emphasis is on the atomic-scale origins of macroscopic materials phenomena. Simulation methods include molecular dynamics and Monte Carlo with applications in thermodynamics, kinetics, and topics in statistical mechanics. Undergraduates register for 165 for 4 units; graduates register for 175 for 3 units. Prerequisites: Undergraduate physics and MATSCI 144 or equivalent coursework in thermodynamics. MATSCI 145 recommended.
Same as: MATSCI 175

MATSCI 166. Data Science and Machine Learning Approaches in Chemical and Materials Engineering. 3 Units.
Application of Data Science, Statistical Learning, and Machine Learning approaches to modern problems in Chemical and Materials Engineering. This course develops data science approaches, including their foundational mathematical and statistical basis, and applies these methods to data sets of limited size and precision. Methods for regression and clustering will be developed and applied, with an emphasis on validation and error quantification. Techniques that will be developed include linear and nonlinear regression, clustering and logistic regression, dimensionality reduction, unsupervised learning, neural networks, and hidden Markov models. These methods will be applied to a range of engineering problems, including conducting polymers, water purification membranes, battery materials, disease outcome prediction, genomic analysis, organic synthesis, and quality control in manufacturing. Prerequisites: CS 106A or permission from instructor.
Same as: CHEMENG 177, CHEMENG 277, MATSCI 176

MATSCI 170. Nanomaterials Laboratory. 3-4 Units.
This course is designed for students interested in exploring the cutting edge of nanoscience and nanotechnology. Students will learn several fundamental concepts related to nanomaterials synthesis and characterization that are commonly used in research and industrial settings. Students will also investigate several applications of nanomaterials through a series of assessments, including self-assembled monolayers, nanowire photovoltaics, and nanoparticles for drug delivery and biomarker screening. In lieu of traditional labs, students will attend weekly discussion sections aimed at priming students to think like a materials engineer. Through these discussions, students will explore how to design an effective experiment, how to identify research gaps, and how to write an effective grant proposal. Enrollment limited to 24. Prerequisites: ENGR 50. Contact instructor for more details. Undergraduates register for 160 for 4 units, Graduates register for 170 for 3 units.
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Lab course. Current electronic and photonic materials and devices. Device physics and micro-fabrication techniques. Students design, fabricate, and perform physical characterization on the devices they have fabricated. Established techniques and materials such as photolithography, metal evaporation, and Si technology; and novel ones such as soft lithography and organic semiconductors. Prerequisite: MATSCI 152 or 199 or consent of instructor. Undergraduates register in 164 for 4 units; graduates register in 174 for 3 units. Students are required to sign up for lecture and one lab section.
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Computational exploration of fundamental topics in materials science using Java-based computation and visualization tools. Emphasis is on the atomic-scale origins of macroscopic materials phenomena. Simulation methods include molecular dynamics and Monte Carlo with applications in thermodynamics, kinetics, and topics in statistical mechanics. Undergraduates register for 165 for 4 units; graduates register for 175 for 3 units. Prerequisites: Undergraduate physics and MATSCI 144 or equivalent coursework in thermodynamics. MATSCI 145 recommended.
Same as: MATSCI 165

MATSCI 176. Data Science and Machine Learning Approaches in Chemical and Materials Engineering. 3 Units.
Application of Data Science, Statistical Learning, and Machine Learning approaches to modern problems in Chemical and Materials Engineering. This course develops data science approaches, including their foundational mathematical and statistical basis, and applies these methods to data sets of limited size and precision. Methods for regression and clustering will be developed and applied, with an emphasis on validation and error quantification. Techniques that will be developed include linear and nonlinear regression, clustering and logistic regression, dimensionality reduction, unsupervised learning, neural networks, and hidden Markov models. These methods will be applied to a range of engineering problems, including conducting polymers, water purification membranes, battery materials, disease outcome prediction, genomic analysis, organic synthesis, and quality control in manufacturing. Prerequisites: CS 106A or permission from instructor.
Same as: CHEMENG 177, CHEMENG 277, MATSCI 166

MATSCI 190. Organic and Biological Materials. 3-4 Units.
Unique physical and chemical properties of organic materials and their uses. The relationship between structure and physical properties, and techniques to determine chemical structure and molecular ordering. Examples include liquid crystals, dendrimers, carbon nanotubes, hydrogels, and biopolymers such as lipids, protein, and DNA. Prerequisite: Thermodynamics and ENGR 50 or equivalent. Undergraduates register for 190 for 4 units; graduates register for 210 for 3 units.
Same as: MATSCI 210

MATSCI 192. Materials Chemistry. 3-4 Units.
An introduction to the fundamental physical chemical principles underlying materials properties. Beginning from basic quantum chemistry, students will learn how the electronic configuration of molecules and solids impacts their structure, stability/reactivity, and spectra. Topics for the course include molecular symmetry, molecular orbital theory, solid-state chemistry, coordination compounds, and nanomaterials chemistry. Using both classroom lectures and journal discussions, students will gain an understanding of and be well-positioned to contribute to the frontiers of materials chemistry, ranging from solar-fuel generation to next-generation cancer treatments. Undergraduates register in 192 for 4 units; graduates register in 202 for 3 units.
Same as: MATSCI 202

MATSCI 193. Atomic Arrangements in Solids. 3-4 Units.
Atomic arrangements in perfect and imperfect solids, especially important metals, ceramics, and semiconductors. Elements of formal crystallography, including development of point groups and space groups. Undergraduates register in 193 for 4 units; graduates register in 203 for 3 units.
Same as: MATSCI 203

MATSCI 194. Thermodynamics and Phase Equilibria. 3-4 Units.
The principles of heterogeneous equilibria and their application to phase diagrams. Thermodynamics of solutions; chemical reactions; non-stoichiometry in compounds; first order phase transitions and metastability; thermodynamics of surfaces, elastic solids, dielectrics, and magnetic solids. Undergraduates register for 194 for 4 units; graduates register for 204 for 3 units.

MATSCI 195. Waves and Diffraction in Solids. 3-4 Units.
The elementary principals of x-ray, vibrational, and electron waves in solids. Basic wave behavior including Fourier analysis, interference, diffraction, and polarization. Examples of wave systems, including electromagnetic waves from Maxwell's equations. Diffracted intensity in reciprocal space and experimental techniques such as electron and x-ray diffraction. Lattice vibrations in solids, including vibrational modes, dispersion relationship, density of states, and thermal properties. Free electron model. Basic quantum mechanics and statistical mechanics including Fermi-Dirac and Bose-Einstein statistics. Prerequisite: MATSCI 193/203 or consent of instructor. Undergraduates register for 195 for 4 units; graduates register for 205 for 3 units.
Same as: MATSCI 205, PHOTON 205

MATSCI 196. Defects in Crystalline Solids. 3-4 Units.
Thermodynamic and kinetic behaviors of 0-D (point), 1-D (line), and 2-D (interface and surface) defects in crystalline solids. Influences of these defects on the macroscopic ionic, electronic, and catalytic properties of materials, such as batteries, fuel cells, catalysts, and memory-storage devices. Undergraduates register for 196 for 4 units; graduates register for 206 for 3 units.
Same as: MATSCI 206

MATSCI 197. Rate Processes in Materials. 3-4 Units.
Diffusion and phase transformations in solids. Diffusion topics: Fick's laws, atomic theory of diffusion, and diffusion in alloys. Phase transformation topics: nucleation, growth, diffusional transformations, spinodal decomposition, and interface phenomena. Material builds on the mathematical, thermodynamic, and statistical mechanical foundations in the prerequisites. Prerequisites: MATSCI 194/204. Undergraduates register for 197 for 4 units; graduates register for 207 for 3 units.
Same as: MATSCI 207

MATSCI 198. Mechanical Properties of Materials. 3-4 Units.
Introduction to the mechanical behavior of solids, emphasizing the relationships between microstructure and mechanical properties. Elastic, anelastic, and plastic properties of materials. The relations between stress, strain, strain rate, and temperature for plastically deformable solids. Application of dislocation theory to strengthening mechanisms in crystalline solids. The phenomena of creep, fracture, and fatigue and their controlling mechanisms. Prerequisites: MATSCI 193/203. Undergraduates register for 198 for 4 units; graduates register for 208 for 3 units.
Same as: MATSCI 208

MATSCI 199. Electronic and Optical Properties of Solids. 3-4 Units.
The concepts of electronic energy bands and transports applied to metals, semiconductors, and insulators. The behavior of electronic and optical devices including p-n junctions, MOS-capacitors, MOSFETs, optical waveguides, quantum-well lasers, light amplifiers, and metallo-dielectric light guides. Emphasis is on relationships between structure and physical properties. Elementary quantum and statistical mechanics concepts are used. Prerequisite: MATSCI 195/205 or equivalent. Undergraduates register for 199 for 4 units; graduates register for 209 for 3 units.
Same as: MATSCI 209

MATSCI 200. Master's Research. 1-15 Unit.
Participation in a research project.

MATSCI 201. Applied Quantum Mechanics I. 3 Units.
Emphasis is on applications in modern devices and systems. Topics include: Schrödinger's equation, eigenfunctions and eigenvalues, solutions of simple problems including quantum wells and tunneling, quantum harmonic oscillator, coherent states, operator approach to quantum mechanics, Dirac notation, angular momentum, hydrogen atom, calculation techniques including matrix diagonalization, perturbation theory, variational method, and time-dependent perturbation theory with applications to optical absorption, nonlinear optical coefficients, and Fermi's golden rule. Prerequisites: MATH 52 and 53, EE 65 or PHYSICS 65 (or PHYSICS 43 and 45).
Same as: EE 222

MATSCI 202. Materials Chemistry. 3-4 Units.
An introduction to the fundamental physical chemical principles underlying materials properties. Beginning from basic quantum chemistry, students will learn how the electronic configuration of molecules and solids impacts their structure, stability/reactivity, and spectra. Topics for the course include molecular symmetry, molecular orbital theory, solid-state chemistry, coordination compounds, and nanomaterials chemistry. Using both classroom lectures and journal discussions, students will gain an understanding of and be well-positioned to contribute to the frontiers of materials chemistry, ranging from solar-fuel generation to next-generation cancer treatments. Undergraduates register in 192 for 4 units; graduates register in 202 for 3 units.
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MATSCI 203. Atomic Arrangements in Solids. 3-4 Units.
Atomic arrangements in perfect and imperfect solids, especially important metals, ceramics, and semiconductors. Elements of formal crystallography, including development of point groups and space groups. Undergraduates register in 193 for 4 units; graduates register in 203 for 3 units.
Same as: MATSCI 193

MATSCI 204. Thermodynamics and Phase Equilibria. 3 Units.
The principles of heterogeneous equilibria and their application to phase diagrams. Thermodynamics of solutions; chemical reactions; non-stoichiometry in compounds; first order phase transitions and metastability; thermodynamics of surfaces, elastic solids, dielectrics, and magnetic solids.Offered online for grad students in summer quarter, while an in-person course for grads and undergrads will be available in winter quarter 2019.

MATSCI 205. Waves and Diffraction in Solids. 3-4 Units.
The elementary principals of x-ray, vibrational, and electron waves in solids. Basic wave behavior including Fourier analysis, interference, diffraction, and polarization. Examples of wave systems, including electromagnetic waves from Maxwell's equations. Diffracted intensity in reciprocal space and experimental techniques such as electron and x-ray diffraction. Lattice vibrations in solids, including vibrational modes, dispersion relationship, density of states, and thermal properties. Free electron model. Basic quantum mechanics and statistical mechanics including Fermi-Dirac and Bose-Einstein statistics. Prerequisite: MATSCI 193/203 or consent of instructor. Undergraduates register for 195 for 4 units; graduates register for 205 for 3 units.
Same as: MATSCI 195, PHOTON 205

MATSCI 206. Defects in Crystalline Solids. 3-4 Units.
Thermodynamic and kinetic behaviors of 0-D (point), 1-D (line), and 2-D (interface and surface) defects in crystalline solids. Influences of these defects on the macroscopic ionic, electronic, and catalytic properties of materials, such as batteries, fuel cells, catalysts, and memory-storage devices. Undergraduates register for 196 for 4 units; graduates register for 206 for 3 units.
Same as: MATSCI 196

MATSCI 207. Rate Processes in Materials. 3-4 Units.
Diffusion and phase transformations in solids. Diffusion topics: Fick's laws, atomic theory of diffusion, and diffusion in alloys. Phase transformation topics: nucleation, growth, diffusional transformations, spinodal decomposition, and interface phenomena. Material builds on the mathematical, thermodynamic, and statistical mechanical foundations in the prerequisites. Prerequisites: MATSCI 194/204. Undergraduates register for 197 for 4 units; graduates register for 207 for 3 units.
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Introduction to the mechanical behavior of solids, emphasizing the relationships between microstructure and mechanical properties. Elastic, anelastic, and plastic properties of materials. The relations between stress, strain, strain rate, and temperature for plastically deformable solids. Application of dislocation theory to strengthening mechanisms in crystalline solids. The phenomena of creep, fracture, and fatigue and their controlling mechanisms. Prerequisites: MATSCI 193/203. Undergraduates register for 198 for 4 units; graduates register for 208 for 3 units.
Same as: MATSCI 198

MATSCI 209. Electronic and Optical Properties of Solids. 3-4 Units.
The concepts of electronic energy bands and transports applied to metals, semiconductors, and insulators. The behavior of electronic and optical devices including p-n junctions, MOS-capacitors, MOSFETs, optical waveguides, quantum-well lasers, light amplifiers, and metallo-dielectric light guides. Emphasis is on relationships between structure and physical properties. Elementary quantum and statistical mechanics concepts are used. Prerequisite: MATSCI 195/205 or equivalent. Undergraduates register for 199 for 4 units; graduates register for 209 for 3 units.
Same as: MATSCI 199

MATSCI 210. Organic and Biological Materials. 3-4 Units.
Unique physical and chemical properties of organic materials and their uses. The relationship between structure and physical properties, and techniques to determine chemical structure and molecular ordering. Examples include liquid crystals, dendrimers, carbon nanotubes, hydrogels, and biopolymers such as lipids, protein, and DNA. Prerequisite: Thermodynamics and ENGR 50 or equivalent. Undergraduates register for 190 for 4 units; graduates register for 210 for 3 units.
Same as: MATSCI 190

MATSCI 213. Microstructure in Materials. 3 Units.
Introduction to fundamental aspects of microstructure in materials that underpin their properties. Evolution of material morphology due to capillary and mechanical forces: surface evolution, coarsening, creep, and sintering. Phase transformations covering nucleation, spinodal and order-disorder transformations. Growth of phases, solidification and precipitation. Surveying technologically relevant morphological and phase transformations in metals, ceramics, and soft materials. Prerequisites: MATSCI 194/204 and 197/207 or equivalent.

MATSCI 214. Structure and Bonding. 3 Units.
Chemical foundations of materials science concerning structure and bonding from a physical and solid-state chemistry perspective. Topics include quantum chemistry; molecular structure, symmetry, and spectroscopy; bonding in molecular orbital, crystal field, and ligand field theories; coordination compounds; chemistry of solid-state metallic, covalent, and ionic materials; introductory defect chemistry; and links to the electronic, optical, and magnetic properties of solid state, polymer, and nanoscale materials.

MATSCI 225. Biochips and Medical Imaging. 3 Units.
The course covers state-of-the-art and emerging bio-sensors, bio-chips, imaging modalities, and nano-therapies which will be studied in the context of human physiology including the nervous system, circulatory system and immune system. Medical diagnostics will be divided into bio-chips (in-vitro diagnostics) and medical and molecular imaging (in-vivo imaging). In-depth discussion on cancer and cardiovascular diseases and the role of diagnostics and nano-therapies.
Same as: EE 225, SBIO 225

MATSCI 230. Materials Science Colloquium. 1 Unit.
May be repeated for credit.

MATSCI 241. Mechanical Behavior of Nanomaterials. 3 Units.
Mechanical behavior of the following nanoscale solids: 2D materials (metal thin films, graphene), 1D materials (nanowires, carbon nanotubes), and 0D materials (metallic nanoparticles, quantum dots). This course will cover elasticity, plasticity and fracture in nanomaterials, defect-scarce nanomaterials, deformation near free surfaces, coupled optoelectronic and mechanical properties (e.g. piezoelectric nanowires, quantum dots), and nanomechanical measurement techniques. Prerequisites: Mechanics of Materials (ME80) or equivalent.
Same as: ME 241

MATSCI 250. Introduction to Materials Science, Biomaterials Emphasis. 3 Units.
Topics include: the relationship between atomic structure and macroscopic properties of man-made and natural materials; mechanical and thermodynamic behavior of surgical implants including alloys, ceramics, and polymers; and materials selection for biotechnology applications such as contact lenses, artificial joints, and cardiovascular stents. No prerequisite.
Same as: ONLINE ONLY

MATSCI 251. Microstructure and Mechanical Properties. 3-4 Units.
Primarily for students without a materials background. Mechanical properties and their dependence on microstructure in a range of engineering materials. Elementary deformation and fracture concepts, strengthening and toughening strategies in metals and ceramics. Topics: dislocation theory, mechanisms of hardening and toughening, fracture, fatigue, and high-temperature creep. Undergraduates register in 151 for 4 units; graduates register for 251 in 3 units.
Same as: MATSCI 151

MATSCI 256. Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution. 3-4 Units.
Operating principles and applications of emerging technological solutions to the energy demands of the world. The scale of global energy usage and requirements for possible solutions. Basic physics and chemistry of solar cells, fuel cells, and batteries. Performance issues, including economics, from the ideal device to the installed system. The promise of materials research for providing next generation solutions.

MATSCI 299. Practical Training. 1 Unit.
Educational opportunities in high-technology research and development labs in industry. Qualified graduate students engage in internship work and integrate that work into their academic program. Following the internship, students complete a research report outlining their work activity, problems investigated, key results, and any follow-on projects they expect to perform. Student is responsible for arranging own employment. See department student services manager before enrolling.

MATSCI 300. Ph.D. Research. 1-15 Unit.
Participation in a research project.

MATSCI 301. Engineering Energy Policy Change. 2 Units.
Public policy and economic decisions profoundly affect all aspects of the energy ecosystem, including its supply, distribution, storage and utilization. These decisions can also influence the pace and focus of innovation of new technologies, including through government-funded research and development programs or regulatory efforts. This course will equip graduate students, who have strong science and engineering backgrounds, with a basic ability to understand and shape the ideation and implementation of sound energy and, related economic, policy. Building on case studies of both aspirational and reactive U.S. energy policy-making, students will design their own policy proposals for new, ambitious and achievable moonshot goals that advance a sustainable and prosperous future. In particular, students will choose a moonshot goal designed to reduce U.S. (and/or global) transportation-related emissions. These proposals may focus on specific mobility technologies (e.g., new zero-GHG liquid fuels), lead to transformation of mobility systems (e.g., integration of wide-scale automation into the transportation sector), or reduce emissions in another way altogether (e.g., moving manufacturing closer to consumption through 3-d printing). Students will also be introduced to gunshot scenarios, moments of energy crisis that require robust response and can create openings for dramatic change to the energy ecosystem.

MATSCI 302. Solar Cells. 3 Units.
In the last 15 years, the solar power market has grown in size by 100 times while solar modules prices have fallen by 20 times. Unsubsidized, solar power projects now compete favorably against fossil fuels in many countries and is on track to be the largest energy provider in the future. How did this happen? nnIn MatSci 302 we will take a comprehensive look at solar cells starting from the underlying device physics that are relevant to all photovoltaic cell technologies. We will then look at the undisputed king (silicon based solar cells); how do they work today and how will they develop in the future. Finally, we will look at why past challengers have failed and how future challengers can succeed. This class will be co-taught by Brian and Craig, who graduated from the Material Science PhD program in 2011 and then started PLANT PV, a startup that developed a solar technology from idea to protoype and then full implementation on production lines in China. The lecturers routinely visit manufacturing facilities in Asia and work closely with engineering staff at the largest solar cell makers in the world to implement their technology into production lines.

MATSCI 303. Principles, Materials and Devices of Batteries. 3 Units.
Thermodynamics and electrochemistry for batteries. Emphasis on lithium ion batteries, but also different types including lead acid, nickel metal hydride, metal air, sodium sulfur and redox flow. Battery electrode materials, electrolytes, separators, additives and electrode-electrolyte interface. Electrochemical techniques; advanced battery materials with nanotechnology; battery device structure. Prerequisites: undergraduate chemistry.

MATSCI 31. Chemical Principles: From Molecules to Solids. 5 Units.
A one-quarter course for students who have taken chemistry previously. This course will introduce the basic chemical principles that dictate how and why reactions occur and the structure and properties of important molecules and extended solids that make up our world. As the Central Science, a knowledge of chemistry provides a deep understanding of concepts in fields ranging from materials, environmental science, and engineering to pharmacology and metabolism. Discussions of molecular structure will describe bonding models including Lewis structures, resonance, crystal-field theory, and molecular-orbital theory. We will reveal the chemistry of materials of different dimensionality, with emphasis on symmetry, bonding, and electronic structure of molecules and solids. We will also discuss the kinetics and thermodynamics that govern reactivity and dictate solubility and acid-base equilibria. A two-hour weekly laboratory section accompanies the course to introduce laboratory techniques and reiterate lecture concepts through hands-on activities. Specific discussions will include the structure, properties, and applications of molecules used in medicine, perovskites used in solar cells, and the dramatically different properties of materials with the same composition (for example: diamond, graphite, graphene). There will be three lectures, one two-hour laboratory session, and an optional 80-minute problem solving session each week. The course will assume familiarity with stoichiometry, unit conversions, and gas laws. All students who are interested in taking general chemistry at Stanford must take the Autumn 2020 General Chemistry Placement Test before Autumn quarter begins, regardless of chemistry background. Generally students earning an AP chemistry score of 4 or higher place into 31M. Students earning an AP score of 5 are also welcome to take the Autumn 2020 Chemistry 33 Placement Test to see if Chem33 is a more appropriate placement. Same as: MATSCI 31.
Same as: CHEM 31M

MATSCI 310. Statistical Mechanics for Materials & Materials Chemistry. 3-4 Units.
This course will cover how thermodynamics evolves from statistical mechanics, with a specific emphasis placed on quantum materials. It will cover distributions for quantum particles, diffusion and aggregation, and a basic discussion of characterizing phase transitions. If time permits, selected topics in quantum information theory will be discussed. Undergraduates register for 4 units; graduates register for 3 units.

MATSCI 312. New Methods in Thin Film Synthesis. 3 Units.
Materials base for engineering new classes of coatings and devices. Techniques to grow thin films at atomic scale and to fabricate multilayers/superlattices at nanoscale. Vacuum growth techniques including evaporation, molecular beam epitaxy (MBE), sputtering, ion beam assisted deposition, laser ablation, chemical vapor deposition (CVD), and electroplating. Future direction of material synthesis such as nanocluster deposition and nanoparticles self-assembly. Relationships between deposition parameters and film properties. Applications of thin film synthesis in microelectronics, nanotechnology, and biology. SCPD offering.

MATSCI 316. Nanoscale Science, Engineering, and Technology. 3 Units.
This course covers important aspects of nanotechnology in nanomaterials synthesis and fabrication, novel property at the nanoscale, tools and applications: a variety of nanostructures including nanocrystal, nanowire, carbon nanotube, graphene, nanoporous material, block copolymer, and self-assembled monolayer; nanofabrication techniques developed over the past 20 years; thermodynamic, electronic and optical property; applications in solar cells, batteries, biosensors and electronics. Other nanotechnology topics may be explored through a group project. SCPD offering.

MATSCI 320. Nanocharacterization of Materials. 3 Units.
Current methods of directly examining the microstructure of materials. Topics: optical microscopy, scanning electron and focused ion beam microscopy, field ion microscopy, transmission electron microscopy, scanning probe microscopy, and microanalytical surface science methods. Emphasis is on the electron-optical techniques. Recommended: 193/203.

MATSCI 321. Transmission Electron Microscopy. 3 Units.
Image formation and interpretation. The contrast phenomena associated with perfect and imperfect crystals from a physical point of view and from a formal treatment of electron diffraction theory. The importance of electron diffraction to systematic analysis and recent imaging developments. Recommended: 193/203, 195/205, or equivalent.

MATSCI 322. Transmission Electron Microscopy Laboratory. 3 Units.
Practical techniques in transmission electron microscopy (TEM): topics include microscope operation and alignment, diffraction modes and analysis, bright-field/dark-field imaging, high resolution and aberration corrected imaging, scanning TEM (STEM) imaging, x-ray energy dispersive spectrometry (EDS) and electron energy loss spectrometry (EELS) for compositional analysis and mapping. Prerequisite: 321, consent of instructor. Enrollment limited to 12.

MATSCI 323. Thin Film and Interface Microanalysis. 3 Units.
The science and technology of microanalytical techniques will be discussed. We consider ways to characterize the structural, compositional, morphological, electronic, optical, mechanical, and magnetic properties of surfaces and interfaces. We will talk about different types of surface analytical techniques that rely on the use of electrons, photons, ions, and sharp tips to learn about different aspects about surfaces. We also discuss strategies on how to combine such techniques to gain a more complete and quantitative picture of a surface. We will also describe the inner workings and design of the hardware involved in analyzing surfaces.n*Prerequisite: some prior exposure to atomic and electronic structure of solids.

MATSCI 326. X-Ray Science and Techniques. 3 Units.
This course provides an introduction to how x-rays interact with matter and how x-ray techniques can be used for developing new understanding of the properties of materials. Course topics include diffraction from ordered and disordered materials, x-ray absorption/emission spectroscopy, photoemission, and coherent scattering. Sources including synchrotrons and x-ray lasers and an introduction to time-resolved techniques. This course includes a parallel laboratory effort in which students will have an opportunity to carry out experiments at the Stanford Synchrotron Radiation Lightsource at the SLAC National Accelerator Laboratory.
Same as: PHOTON 326

MATSCI 331. Atom-based computational methods for materials. 3 Units.
Introduction to atom-based computational methods for materials with emphasis on quantum methods. Topics include density functional theory, tight-binding and empirical approaches. Computation of optical, electronic, phonon properties. Bulk materials, interfaces, nanostructures. Molecular dynamics. Prerequisites - undergraduate quantum mechanics.

MATSCI 341. Quantum Theory of Electronic and Optical Excitations in Materials. 3 Units.
Introduction to the fundamentals of solid-state physics and materials science, with emphasis in electronic and optical excitation processes. We will develop quantum formalisms to understand concepts including: elementary excitations in materials, crystal symmetry and Bloch¿s theorem, electronic bandstructure and methods to compute it (including tight-binding and density-functional theory), linear response theory, dielectric functions, as well as electronic transitions and optical properties of solids. We apply these methods to understand the electronic and optical properties of real materials, including bulk metals, semiconductors, and 2D materials.

MATSCI 343. Organic Semiconductors for Electronics and Photonics. 3 Units.
The science of organic semiconductors and their use in electronic and photonic devices. Topics: methods for fabricating thin films and devices; relationship between chemical structure and molecular packing on properties such as band gap, charge carrier mobility and luminescence efficiency; doping; field-effect transistors; light-emitting diodes; lasers; biosensors; photodetectors and photovoltaic cells.

MATSCI 346. Nanophotonics. 3 Units.
Recent developments in micro- and nanophotonic materials and devices. Basic concepts of photonic crystals. Integrated photonic circuits. Photonic crystal fibers. Superprism effects. Optical properties of metallic nanostructures. Sub-wavelength phenomena and plasmonic excitations. Meta-materials. Prerequisite: Electromagnetic theory at the level of 242.
Same as: EE 336

MATSCI 347. Magnetic materials in nanotechnology, sensing, and energy. 3 Units.
This course will teach the fundamentals of magnetism, magnetic mateirals, and magnetic nanostructures and their myriad of applications in nanotechnology, sensing, energy and related areas. The scope of the course include: atomic origins of magnetic moments, magnetic exchange and ferromagnetism, types of magnetic order, magnetic anisotropy, domains, domain walls, hysteresis loops, hard and soft magnetic materials, demagnetization factors, magnetic nanoparticles and nanostructures, spintronics, and multiferroics. The key applications include electromagnet and permanent magnet, magnetic inductors, magnetic sensors, magnetic memory, hard disk drives, energy generation and harvesting, biomagnetism, etc. Prerequisites: College level electricity and magnetism course or equivalent.

MATSCI 358. Fracture and Fatigue of Materials and Thin Film Structures. 3 Units.
Linear-elastic and elastic-plastic fracture mechanics from a materials science perspective, emphasizing microstructure and the micromechanisms of fracture. Plane strain fracture toughness and resistance curve behavior. Mechanisms of failure associated with cohesion and adhesion in bulk materials, composites, and thin film structures. Fracture mechanics approaches to toughening and subcritical crack-growth processes, with examples and applications involving cyclic fatigue and environmentally assisted subcritical crack growth. Prerequisite: 151/251, 198/208, or equivalent. SCPD offering.
Same as: ME 258

MATSCI 380. Nano-Biotechnology. 3 Units.
Literature based. Principles that make nanoscale materials unique, applications to biology, and how biological systems can create nanomaterials. Molecular sensing, drug delivery, bio-inspired synthesis, self-assembling systems, and nanomaterial based therapies. Interactions at the nanoscale. Applications and opportunities for new technology.

MATSCI 381. Biomaterials in Regenerative Medicine. 3 Units.
Materials design and engineering for regenerative medicine. How materials interact with cells through their micro- and nanostructure, mechanical properties, degradation characteristics, surface chemistry, and biochemistry. Examples include novel materials for drug and gene delivery, materials for stem cell proliferation and differentiation, and tissue engineering scaffolds. Prerequisites: undergraduate chemistry, and cell/molecular biology or biochemistry.
Same as: BIOE 361

MATSCI 384. Materials Advances for Neurotechnology: Materials Meet the Mind. 3 Units.
The dichotomy between the material world and the mental world has driven the curiosity of scientists to explore the wonders of the brain, as well as motivated the continued innovations of novel technologies based on advances in materials science and engineering to understand the brain. This course introduces the basic principles of materials design and fabrication for probing the inner workings of the brain, discusses the fundamental challenges of state-of-the-art neurotechnologies, and explores the latest breakthroughs in materials-assisted neuroengineering. The course will cover the following topics: fundamentals of electrophysiology of the nervous system, mechanical and biochemical requirements of neural interfacing materials, materials for electrical neural interfaces (tungsten/carbon electrodes, Utah/Michigan/ECoG electrode arrays), materials for optical neural interfaces (optical fibers/waveguides for optogenetics, microprisms/GRIN lenses for fluorescence imaging of neural activity), and materials for biochemical neural interfaces (implantable microfluidic probes, neurotrophic scaffolds). Students will be able to speak the languages of both materials science and neuroengineering and acquire the knowledge and skills to understand and address pressing neuroscience challenges with materials advances. This course will include lectures, student discussions/presentations and guest lectures given by pioneers in related fields at Stanford and other schools/companies in the local area. nPrerequisite: undergraduate physics and chemistry; MATSCI 152, 158, 164, 190 or equivalents are recommended but not required prior to taking this course.

MATSCI 385. Biomaterials for Drug Delivery. 3 Units.
Fundamental concepts in engineering materials for drug delivery. The human body is a highly interconnected network of different tissues and there are all sorts of barriers to getting pharmaceutical drugs to the right place at the right time. Topics include drug delivery mechanisms (passive, targeted), therapeutic modalities and mechanisms of action, engineering principles of controlled release and quantitative understanding of drug transport, chemical and physical characteristics of delivery molecules and assemblies, significance of biodistribution and pharmacokinetic models, toxicity of biomaterials and drugs, and immune responses.
Same as: BIOE 385

MATSCI 399. Graduate Independent Study. 1-10 Unit.
Under supervision of a faculty member.

MATSCI 400. Participation in Materials Science Teaching. 1-3 Unit.
May be repeated for credit.

MATSCI 801. TGR Project for MS Students. 0 Units.
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MATSCI 802. TGR Dissertation for Ph.D Students. 0 Units.
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MATSCI 81N. Bioengineering Materials to Heal the Body. 3 Units.
Preference to freshmen. Real-world examples of materials developed for tissue engineering and regenerative medicine therapies. How scientists and engineers design new materials for surgeons to use in replacing body parts such as damaged heart or spinal cord tissue. How cells interact with implanted materials. Students identify a clinically important disease or injury that requires a better material, proposed research approaches to the problem, and debate possible engineering solutions.

MATSCI 82N. Science of the Impossible. 3 Units.
Imagine a world where cancer is cured with light, objects can be made invisible, and teleportation is allowed through space and time. The future once envisioned by science fiction writers is now becoming a reality, thanks to advances in materials science and engineering. This seminar will explore 'impossible' technologies - those that have shaped our past and those that promise to revolutionize the future. Attention will be given to both the science and the societal impact of these technologies. We will begin by investigating breakthroughs from the 20th century that seemed impossible in the early 1900s, such as the invention of integrated circuits and the discovery of chemotherapy. We will then discuss the scientific breakthroughs that enabled modern 'impossible' science, such as photodynamic cancer therapeutics, invisibility, and psychokinesis through advanced mind-machine interfaces. Lastly, we will explore technologies currently perceived as completely impossible and brainstorm the breakthroughs needed to make such science fiction a reality. The course will include introductory lectures and in-depth conversations based on readings. Students will also be given the opportunity to lead class discussions on a relevant 'impossible science' topic of their choosing.

MATSCI 83N. Great Inventions That Matter. 3 Units.
This introductory seminar starts by illuminating on the general aspects of creativity, invention, and patenting in engineering and medicine, and how Stanford University is one of the world's foremost engines of innovation. We then take a deep dive into some great technological inventions which are still playing an essential role in our everyday lives, such as fiber amplifier, digital compass, computer memory, HIV detector, personal genome machine, cancer cell sorting, brain imaging, and mind reading. The stories and underlying materials and technologies behind each invention, including a few examples by Stanford faculty and student inventors, are highlighted and discussed. A special lecture focuses on the public policy on intellectual properties (IP) and the resources at Stanford Office of Technology Licensing (OTL). Each student will have an opportunity to present on a great invention from Stanford (or elsewhere), or to write a (mock) patent disclosure of his/her own ideas.

MATSCI 85N. Health Fab: Making Stuff for Life. 3 Units.
Semiconductor-based chip technology is all around us; in our phones, computers, and cars. However, not all capabilities developed for silicon processing are directed towards computers and mobile devices. A new field has emerged using these fabrication and patterning techniques for medical devices, health monitoring, and human-machine interfaces. We can now create chips that flow not electrons, but liquids, taking samples and performing analyses. These liquid based functions can be integrated together with silicon electronic devices for sensing, control, or manipulation. FitBits and Apple Watches are examples of the first generation of 'wearable' electronics, while more advanced devices that incorporate both liquid based sensors and electronics are on their way.nnIn this class, we will learn some fundamentals of device fabrication for biomedical purposes, take you inside the Stanford NanoFabrication Facility (SNF), and create microfluidic devices. We will cover what is possible with current microfabrication techniques, including direct-write lithography, laser cutting, three-dimensional two photon patterning, polymer deposition and metal patterning. Students will learn how to design, fabricate, and test microfluidic and biomedically related devices. In addition to teaching and hands-on training in microfluidic fabrication, the class will include four team-based projects, each with a different device goal. These projects requirements will be submitted by leading research groups at Stanford, providing up-to-date and real world challenges. Each team will work together to identify specific device needs, invent solutions, and built prototype devices. At the end of the course each team will present its designs to the sponsoring research program and describe how they met the required objectives. No prior experience with device fabrication is needed.

MATSCI 90Q. Resilience, Transformation, and Equilibrium: the Science of Materials. 3-4 Units.
In this course, we will explore the fundamentals of the kinetics of materials while relating them to different phenomena that we observe in our everyday lives. We will study the mechanisms and processes by which materials obtain the mechanical, electronic, and other properties that make them so useful to us. How can we cool water below freezing and keep it from turning into ice? Why is it that ice cream that has been in the freezer for too long does not taste as good? What are crystal defects and why do they help create some of the most useful (semiconductors) and beautiful (gemstones) things we have? This introductory seminar is open to all students, and prior exposure to chemistry, physics, or calculus is NOT required.