DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

Materials science and engineering (MSE) studies the ways in which atoms and molecules can be built into solid materials and how the structural arrangement of the atoms in a material governs its properties. The department's research and academic programs address all classes of materials, used in every domain of human endeavor, including energy, sustainability, nanotechnology, healthcare, information technology, and manufacturing. Because almost all technological advances are based upon materials advances, MSE is unique for its balance of basic science (examining the relationships and connections between processing, structure, and properties of materials) and practical applications. The department draws on scientific perspectives from chemistry, physics, biology, computational, and mathematical approaches, and engineering, economics, and industrial design.

Recent advances in materials have depended as much on advances in materials engineering as they have on materials science. When developing engineering processes for the production of materials and when designing materials for specific applications, the materials scientist and engineer must understand fundamental concepts such as thermodynamics, kinetics, and atomic structure, as well as economic, social, and environmental factors. Today's materials scientists and engineers address some of the key challenges facing humanity, including sustainable energy generation and storage, the environmental impact of human activities, and advancements in health and medicine.

The fundamental concepts and applications of materials science and engineering are taught within core subjects and electives at the undergraduate and graduate levels. Undergraduate lectures are complemented by a variety of laboratory experiences. By selecting appropriate subjects, students can follow many different paths with emphasis on engineering, science, or a mixture of the two. In addition, students may pursue a path in archaeology and archaeological science within the Department of Materials Science and Engineering and the Center for Materials Research in Archaeology and Ethnology (CMRAE) (*http://web.mit.edu/cmrae*). This curriculum is unique within departments of anthropology, archaeology, and engineering.

Materials engineers and materials scientists are continually in high demand by industry and government for jobs in research, development, production, and management. They find a diversity of challenging opportunities in industries related to energy, the environment, electronics, aerospace, consumer products, biomaterials, and medicine, as well as in national laboratories, consulting, and entrepreneurship. A large number of DMSE alumni are faculty at leading universities.

The department has extensive undergraduate materials teaching laboratories containing a wide range of materials processing and characterization equipment. The Undergraduate Teaching Laboratory on the Infinite Corridor includes facilities for biomaterials research, chemical synthesis, and physical and electronic properties measurement. The Breakerspace characterization lab allows undergraduates to explore scanning electron microscopy, X-ray diffraction, and Raman spectrometry. The Laboratory for Advanced Materials contains thermal, electrical, optical, and magnetic characterization equipment. The Laboratory for Engineering Materials has machining and 3D printing capabilities. The Nanomechanics Laboratory has a suite of equipment for probe microscopy and mechanical and tribological measurements. Other departmental laboratories include facilities for preparation of a variety of bulk and thin film materials, and characterization by optical, electron (TEM, SEM), and scanning probe (AFM, STM) microscopy, and electrical, optical, magnetic, and mechanical property measurements. DMSE faculty, students, and staff also access the materials characterization tools in the Materials Research Laboratory (*https://catalog.mit.edu/mit/research/materials-research-laboratory*) and the cleanroom facilities and tools in MIT.nano (*https://mitnano.mit.edu*), including state of the art electron microscopy.

Undergraduate Study

The Department of Materials Science and Engineering (DMSE) offers several undergraduate degree programs:

- Course 3, leading to the Bachelor of Science in Materials Science and Engineering, is taken by the majority of undergraduates in the department and is accredited by the Engineering Accreditation Commission of Accreditation Board for Engineering and Technology (ABET) (*http://www.abet.org*).
- Course 3-A, leading to the Bachelor of Science as Recommended by the Department of Materials Science and Engineering, provides students greater flexibility in designing their own self-guided program. The New Engineering Education Transformation (NEET) program (*https://neet.mit.edu*) offers a thread in Advanced Materials Machines that meets the 3-A requirements.
- Course 3-C leads to the Bachelor of Science in Archaeology and Materials as Recommended by the Department of Materials Science and Engineering.

The department also offers research and educational specialization in a large number of industrially and scientifically important areas leading to master's and doctoral degrees.

Bachelor of Science in Materials Science and Engineering (Course 3)

The undergraduate program (*https://catalog.mit.edu/degree-charts/materials-science-engineering-course-3*) serves the needs of students who intend to pursue employment in materials-related industries immediately upon graduation, as well as those who will do graduate work in the engineering or science of materials. The program is designed to be started at the beginning of the sophomore year, although it can be started in the spring term of the sophomore year or in the junior year with some loss of scheduling flexibility.

The first four academic terms of the program contain required core subjects that address the fundamental relations between processing, microstructure, properties, and applications of modern materials. The core subjects are followed by a sequence of restricted electives that provide more specialized coverage of the major classes of modern materials: biomaterials, ceramics, electronic materials, metals, and polymers, as well as cross-cutting topics relevant to all types of materials. Course 3 students write either a senior thesis or reports based on industrial internships. This provides an opportunity for original research work beyond that which occurs elsewhere in the program.

The required subjects can be completed in the sophomore and junior years within a schedule that allows students to take a HASS subject each term and a range of elective junior and senior subjects. Departmental advisors assist students in selecting elective subjects. While the program should satisfy the academic needs of most students, petitions for variations or substitutions may be approved by the departmental Undergraduate Committee; students should contact their advisor for guidance in such cases.

Participation in laboratory work by undergraduates is an integral part of the curriculum. The departmental core subjects include extensive laboratory exercises, which investigate materials properties, structure, and processing and are complementary to the lecture subjects. The junior-year core includes a capstone laboratory subject, 3.042 Materials Project Laboratory, that emphasizes design, materials processing, teamwork, communication skills, and project management. Undergraduate students also have access to extensive facilities for research in materials as part of the Undergraduate Research Opportunities Program (UROP) (*http://uaap.mit.edu/research-exploration/urop*) and thesis projects. Engineering design figures prominently in a substantial portion of the laboratory exercises. Students develop oral and written communication skills by reporting data and analysis in a variety of ways.

Students in Course 3 are required to complete an intensive research field experience by participating in either the Internship Program or the Thesis Program. Both programs are conducted under the supervision of faculty members and extend curricular topics to real-world contexts and applications. The internship program consists of completing two paid internships with a significant materials component, typically conducted in the summer after the sophomore (3.930 Internship Program) and junior (3.931 Internship Program) years. The thesis program (3.THU Undergraduate Thesis) consists of a significant materials research project in a faculty laboratory. Both programs conclude with a formal presentation of findings.

Bachelor of Science as Recommended by the Department of Materials Science and Engineering (Course 3-A)

Some students may be attracted to the many opportunities available in the materials discipline but also have special interests that are not satisfied by the Course 3 program. For instance, some students may wish to take biology and chemistry subjects in preparation for medical school or management subjects prior to entering an MBA or law program, or they may wish to explore AI and computational methods in order to apply them to materials discovery and design or predictive modeling. In these cases, the 3-A program may be of value as a more flexible curriculum in which a larger number of elective choices is available.

The curriculum requirements for Course 3-A (*https://catalog.mit.edu/degree-charts/materials-science-engineering-course-3-a*) are similar to but more flexible than those for Course 3.

A student considering the 3-A program should contact the department Academic Office, who will counsel them more fully on the academic considerations involved. The student will prepare a complete plan of study which must be approved by the departmental Undergraduate Committee. This approval must be obtained no later than the beginning of the student's junior year. The student is then expected to adhere to this plan unless circumstances require a change, in which case a petition for a modified program must be submitted to the Undergraduate Committee. The department does not seek ABET accreditation for the 3-A program.

Bachelor of Science in Archaeology and Materials as Recommended by the Department of Materials Science and Engineering (Course 3-C)

Students who have a specific interest in archaeology and archaeological science may choose Course 3-C. The 3-C program (*https://catalog.mit.edu/degree-charts/archaeology-materials-course-3-c*) is designed to afford students broad exposure to fields that contribute fundamental theoretical and methodological approaches to the study of ancient and historic societies. The primary fields include anthropological archaeology, geology, and materials science and engineering. The program enriches knowledge of past and present-day nonindustrial societies by making the natural and engineering sciences part of the archaeological tool kit.

The program's special focus is on understanding prehistoric culture through study of the structure and properties of materials associated with human activities. Investigating peoples' interactions with materials, the objects that such interactions produced, and the related environmental settings leads to a fuller analysis of the physical, social, cultural, and ideological world in which people function. These are the goals of anthropological archaeology, goals that are reached, in part, through science and engineering perspectives.

Participation in laboratory work by undergraduates is an integral part of the curriculum. The program requires that all students take a materials laboratory subject. Many of the archaeology subjects are designed with a laboratory component; such subjects meet in the Undergraduate Archaeology and Materials Laboratory. Undergraduate students also have access to the extensive CMRAE (*https://cmrae.mit.edu*) facilities for research in archaeological materials as part of UROP and thesis projects. Such projects may include archaeological fieldwork during IAP or the summer months.

The **HASS Concentration in Archaeology and Archaeological Science** provides concentrators with a basic knowledge of the field of archaeology, the systematic study of the human past. Students pursuing the SB in 3-C may not also concentrate in this area. The archaeology and archaeological science concentration consists of four subjects:

Required Subjects		
3.986[J]	The Human Past: Introduction to Archaeology	12
3.985[J]	Archaeological Science	9
Select two other HASS electives from among the following:		18-21
3.094[J]	Materials in Human Experience	
3.982	The Ancient Andean World	
3.983	Ancient Mesoamerican Civilization	
3.987	Human Evolution: Data from Palaeontology, Archaeology, and Materials Science	
3.993	Archaeology of the Middle East	
Total Units		**39-42**

The department does not seek ABET accreditation for the 3-C program. Students may contact Dr. Max Price (maxprice@mit.edu) for more information.

Minor in Materials Science and Engineering

Required Subjects		
3.010	Structure of Materials	12
3.020	Thermodynamics of Materials	12
Core Subjects (Select 2)		**24**
3.013	Mechanics of Materials	
3.023	Synthesis and Design of Materials	
3.030	Microstructural Evolution in Materials	
3.033	Electronic, Optical and Magnetic Properties of Materials	
3.044	Materials Processing	
3.042	Materials Project Laboratory	
Restricted Electives (Select 2)		**24**
Select 2 subjects from the list of Restricted Electives in Course 3/3-A.		
Total Units		**72**

With the approval of the minor advisor, students may substitute one subject taken outside the department for one of the core or restricted elective subjects, provided that the coverage of the substituted subject is similar to one of those in the departmental program. A minimum of 60 units must be Course 3 subject units, with the exception being if the minor proposal includes 18.03. In this case, a minimum of 48 Course 3 credits may be approved. Examples of minor programs in materials science and engineering can be obtained from the department.

Minor in Archaeology and Materials

The Minor in Archaeology and Materials (3-C) consists of six undergraduate subjects as described below.

Required Subjects		
3.010	Structure of Materials	12
3.020	Thermodynamics of Materials	12
3.030	Microstructural Evolution in Materials	12
3.985[J]	Archaeological Science (HASS-S)	9
3.986[J]	The Human Past: Introduction to Archaeology (HASS-S)	12
Elective		
Select one of the following: [1]		9-12
3.981	Communities of the Living and the Dead: the Archaeology of Ancient Egypt	
3.982	The Ancient Andean World	
3.983	Ancient Mesoamerican Civilization	
3.987	Human Evolution: Data from Palaeontology, Archaeology, and Materials Science	
3.990	Seminar in Archaeological Method and Theory	
3.993	Archaeology of the Middle East	
Total Units		**66-69**

[1] *All of these subjects, with the exception of 3.990, provide HASS-S credit.*

With the approval of the minor advisor, students may substitute one subject taken outside the Course 3 program, provided the coverage is equivalent. The 3-C minor advisor, Dr. Franco Rossi, will ensure that the minor program forms a coherent group of subjects.

A general description of the minor program (*https://catalog.mit.edu/mit/undergraduate-education/academic-programs/minors*) may be found under Undergraduate Education.

Inquiries

Additional information regarding undergraduate programs may be obtained from the DMSE Academic Office at dmse-ugoffice@mit.edu.

Graduate Study

The Department of Materials Science and Engineering (DMSE) offers the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science in Materials Science and Engineering. The department also offers opportunities for interdisciplinary study through the programs in Archaeological Materials, Computational Science and Engineering, Polymers and Soft Matter, and Technology and Policy.

Admission Requirements for Graduate Study

General admissions requirements (*https://catalog.mit.edu/mit/graduate-education/general-degree-requirements*) are described under Graduate Education. Programs are arranged on an individual basis depending upon the preparation and interests of the student. Those who have not studied some thermodynamics and kinetics at the undergraduate level are expected to know the material covered in 3.010 Structure of Materials, 3.020 Thermodynamics of Materials, and 3.030 Microstructural Evolution in Materials.

Requirements for Completion of Graduate Degrees

The general requirements (*https://catalog.mit.edu/mit/graduate-education/general-degree-requirements*) for completion of graduate degrees are also described under the section on Graduate Education. Students completing a Master of Science degree are required to present a seminar summarizing the thesis. The department requires that candidates for the doctoral degrees go through a qualifying procedure and pass Institute-mandated general written and oral examinations before continuing with their programs of study and research, and that they satisfy a minor requirement. Information on the qualifying procedure and on the subject areas covered by the general examinations is available in the DMSE Academic Office.

Master of Science in Materials Science and Engineering

The department offers a Master of Science degree in materials science and engineering. The general requirements for the master's degree (*https://catalog.mit.edu/mit/graduate-education/general-degree-requirements*) are described under the section on Graduate Education. The coherent program of subjects (34 units, though not necessarily all DMSE subjects) must be approved by the Department Committee on Graduate Students. Of the 66 total units required for the master's degree, 42 graduate degree credits are required to be in DMSE subjects at the graduate level. The thesis must have significant materials research content. An internal departmental thesis reader is required if the student's advisor is outside DMSE.

The department may also recommend awarding a master's degree without departmental specification; the general requirements (*https://catalog.mit.edu/mit/graduate-education/general-degree-requirements*) are described under Graduate Education. The thesis must be materials-related. An internal departmental thesis reader is required if the thesis advisor is outside DMSE.

Simultaneous Award of Two Master of Science Degrees for Students from Other Departments

Graduate students may seek two Master of Science degrees simultaneously or in sequence, one awarded by the student's home department and the other by the Department of Materials Science and Engineering. The rules governing dual degrees (*https://catalog.mit.edu/mit/graduate-education/general-degree-requirements*) are found in the section detailing degree requirements under Graduate Education. Additional information on requirements that must also be met to obtain the Master of Science degree from the Materials Science and Engineering Department is available from the department.

Doctoral Degree in Materials Science and

The Department of Materials Science and Engineering (DMSE) offers a Doctor of Philosophy (PhD) and Doctor of Science (ScD) in Materials Science and Engineering (*https://catalog.mit.edu/degree-charts/phd-materials-science-engineering*); the program is the same for both degrees. The DMSE doctoral program provides an advanced educational experience that is versatile, intellectually challenging, and of enduring value for high-level careers relating to the generation and application of knowledge concerning materials. It develops students' ability, confidence, and originality to grasp and solve challenging problems involving materials.

All students in the DMSE doctoral program have the same foundation of core requirements: four core subjects, two seminar-based courses, and first-year thesis research requirements. The courses define what the department considers to be the fundamental knowledge that serves as the basis of materials science and engineering as a discipline—what every PhD materials scientist or materials engineer from MIT ought to know. The first-year student seminars and core subjects provide a rigorous, unified foundation for subsequent advanced-level subjects and thesis research. The successful completion of the core requirements is assessed via the student's performance in each subject.

Each doctoral student must take three post-core electives, selected from among the graduate subjects offered by the department (*https://catalog.mit.edu/subjects/3*) and approved by the thesis committee. A full range of advanced-level subjects is offered in a variety of topics, and arrangements can be made for individually planned study of any relevant topic. In addition, students are required to take a two- or three-subject minor program.

Students in the DMSE doctoral program must successfully complete the general examination, which consists of written and oral evaluations to qualify as a candidate for the doctoral degree:

- A core curriculum assessment and review of research progress during the first year of the graduate program
- A thesis area examination, in which each student is expected to demonstrate a general understanding of the fundamentals of their chosen field and deeper understanding of one or more of its significant aspects that specifically relate to their thesis topic, as reflected in their chosen elective and minor subjects. The thesis area examination includes submission of a written thesis proposal and an oral examination.

Doctoral candidates (who have passed the general examination) must complete a doctoral thesis that satisfies the Institute (*https://catalog.mit.edu/mit/graduate-education/general-degree-requirements/#doctoraldegreetext*) and departmental requirements to receive the doctoral degree. During their first semester, students will meet with faculty members and evaluate research opportunities available in each lab. Selection of a research lab and thesis project is done by the student with the understanding that the student and faculty member mutually agree on the general topic and content area of the thesis. The research culminates in the writing of a thesis document. The results of the research must be of sufficient significance to warrant publication in the scientific literature; depending on the research field, this publication can come in the form of journal articles, conference proceedings, patents, or combinations of these or other public disclosure formats. Visit the DMSE website for additional information on the doctoral program (*https://dmse.mit.edu/graduate/programs/doctoral*).

Interdisciplinary Programs

Program in Archaeological Materials

The Department of Materials Science and Engineering offers an interdisciplinary doctoral program for individuals who wish to consider the study of archaeology and materials science and pursue research in the field of archaeological materials. Admission to the program is through the department. The program requires four core subjects—half in materials science and engineering, half in archaeology—and six additional subjects. Many of the subject requirements may be met with coursework in the Architecture; Civil and Environmental Engineering; Earth, Atmospheric, and Planetary Sciences; Mechanical Engineering; and Urban Studies and Planning departments; or in the Technology and Policy Program; the Program in Science, Technology, and Society; and the Anthropology Department at Harvard University. Field research opportunities are available, most notably in Mesoamerica and South America.

Computational Science and Engineering

The Computational Science and Engineering (CSE) doctoral program (*https://cse.mit.edu/programs/phd*) allows students to specialize in a computation-related field of their choice through focused coursework and a doctoral thesis through a number of participating host departments. The CSE PhD program is administered jointly by the Center for Computational Science and Engineering (CCSE) and the host departments, with the emphasis of thesis research activities being the development of new computational methods and/or the innovative application of computational techniques to important problems in engineering and science.

For more information, see the program descriptions (*https://catalog.mit.edu/interdisciplinary/graduate-programs/computational-science-engineering*) under Interdisciplinary Graduate Programs.

Polymers and Soft Matter

The Program in Polymers and Soft Matter (PPSM) (*http://polymerscience.mit.edu*) offers students from participating departments an interdisciplinary core curriculum in polymer science and engineering, exposure to the broader polymer community through seminars, contact with visitors from industry and academia, and interdepartmental collaboration while working towards a PhD or ScD degree.

Research opportunities include functional polymers, controlled drug delivery, nanostructured polymers, polymers at interfaces, biomaterials, molecular modeling, polymer synthesis, biomimetic materials, polymer mechanics and rheology, self-assembly, and polymers in energy. The program is described in more detail (*https://catalog.mit.edu/interdisciplinary/graduate-programs/polymers-soft-matter*) under Interdisciplinary Graduate Programs.

Technology and Policy Program

The Master of Science in Technology and Policy is an engineering research degree with a strong focus on the role of technology in policy analysis and formulation. The Technology and Policy Program (TPP) curriculum provides a solid grounding in technology and policy by combining advanced subjects in the student's chosen technical field with courses in economics, politics, and law. Many students combine TPP's curriculum with complementary subjects to obtain dual degrees in and either a specialized branch of engineering or an applied social science such as political science or urban studies and planning. For additional information, see the program description (*https://catalog.mit.edu/interdisciplinary/graduate-programs/technology-policy*) under Interdisciplinary Programs or visit the program website (*http://tpp.mit.edu*).

Financial Support

The Department of Materials Science and Engineering offers assistantships and fellowships for graduate study. Research and teaching assistantships are available in the fields in which the department is active.

Inquiries

Contact the Academic Office at dmse-gradoffice@mit.edu for additional information regarding graduate programs, admissions, and financial aid.

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3.000 Coffee Matters: Using the Breakerspace to Make the Perfect Cup
Prereq: None
U (Spring)
3-0-0 units

Uses the Course 3 (DMSE) Breakerspace to delve into the world of materials science through brewing, sipping, and testing several forms of coffee and espresso. Presents cutting-edge materials characterization tools, including optical and electron microscopes, spectroscopy techniques, and hardness/strength testing. Through experiments to analyze the composition and microstructure of coffee beans, grinds, and brewing equipment, students have the opportunity to learn how material properties influence the taste, aroma, and quality of espresso. Equips students with the knowledge and skills to appreciate coffee on a whole new level through application of materials characterization techniques, consideration of relevant physics and chemistry, and sampling. Subject can count toward the 6-unit discovery-focused credit limit for first-year students.
J. Grossman, J. Lavallee

3.001 Science and Engineering of Materials
Prereq: None
U (Spring)
2-0-1 units

Provides a broad introduction to topics in the Department of Materials Science and Engineering's core subjects. Classes emphasize hands-on activities and conceptual and visual examples of materials phenomena and materials engineering, interspersed with guest speakers from inside and outside academia to show career paths. Subject can count toward the 6-unit discovery-focused credit limit for first year students. Preference to first-year students.
K. Kolenbrander, F. M. Ross

3.002 Materials for Energy and Sustainability
Prereq: None
U (Fall)
2-0-1 units

Materials play a central role in the ongoing global transformation towards more sustainable means of harvesting, storing, and conserving energy, through better batteries, fuel cells, hydrogen electrolyzers, photovoltaics, and the like. Methods for producing materials such as cement, steel, ammonia, and ethylene, which rank amongst today's largest industrial emitters of greenhouse gases, are being re-invented. Much of this work is taking place at MIT and surrounding cleantech startups. This class discusses the underlying science of selected new technologies, the challenges which must be overcome, and the magnitude of their potential impact. Visits to the startups behind each case study and meetings with the scientists and engineers creating these technologies are included. Subject can count toward 6-unit discovery-focused credit limit for first-year students. Preference to first-year students.
Y. Chiang

3.003 Small Planet Engineering: Climate, Energy, and Sustainability
Subject meets with 3.004
Prereq: Calculus I (GIR) and Physics I (GIR)
U (Spring)
3-0-6 units

Introduces students to the interdisciplinary nature of 21st-century engineering projects with three threads of learning: a technical toolkit, a social science toolkit, and a methodology for problem-based learning. Students encounter the social, political, economic, and technological challenges of engineering practice via case studies and engineering projects focused on climate, energy, and sustainability. Includes a six-stage term project in which student teams develop solutions through exercises in project planning, analysis, design, optimization, demonstration, reporting, and team building. 3.004 includes an additional solar cell design and fabrication project. Preference to first-year students.
L. Kimerling

3.004 Small Planet Engineering: Climate, Energy, and Sustainability
Subject meets with 3.003
Prereq: Calculus I (GIR) and Physics I (GIR)
U (Spring)
3-1-8 units

Introduces students to the interdisciplinary nature of 21st-century engineering projects with three threads of learning: a technical toolkit, a social science toolkit, and a methodology for problem-based learning. Students encounter the social, political, economic, and technological challenges of engineering practice via case studies and engineering projects focused on climate, energy, and sustainability. Includes a six-stage term project in which student teams develop solutions through exercises in project planning, analysis, design, optimization, demonstration, reporting, and team building. 3.004 includes an additional solar cell design and fabrication project.
L. Kimerling

3.006 NEET Seminar: Advanced Materials Machines
Prereq: Permission of instructor
U (Fall, Spring)
1-0-2 units
Can be repeated for credit.

Seminar for students enrolled in the Advanced Materials Machines NEET thread. Focuses on topics around innovative materials manufacturing via guest lectures and research discussions.
E. Olivetti

3.0061[J] Introduction to Design Thinking and Rapid Prototyping
Same subject as 22.03[J]
Prereq: None
U (Fall)
2-2-2 units

See description under subject 22.03[J]. Enrollment limited; preference to Course 22 & Course 3 majors and minors, and NEET students.
M. Short, E. Olivetti

3.009 Materials, Mechanics, and Flight: Birds, an Engineer¿s Delight
Prereq: None
U (Spring)
Not offered regularly; consult department
2-2-5 units

Examines how birds work from an engineering perspective and how engineers design materials, lightweight structures, and aircraft using concepts learned from birds. Topics include: materials science of feathers, and how engineers design materials for structural color, thermal insulation, and water repellency; how feathers can create or suppress sound, and how engineers reduce the sound produced by wind turbine blades by mimicking barn owl flight feathers; mechanics of bird bones, structural weight reduction, and its applications to lightweight structures; how birds fly, how the Wright brothers studied bird flight to design their plane, and how modern aircraft fly. Design project allows students to explore different fields of engineering. Preference given to first-year students.
L. Gibson

3.010 Structure of Materials
Prereq: Chemistry (GIR); *Coreq: 18.03 or 18.032*
U (Fall)
3-2-7 units. Institute LAB

Describes the fundamentals of bonding and structure that underpin materials science. Structure of noncrystalline, crystalline, and liquid-crystalline states across length scales including short and long range ordering. Point, line, and surface imperfections in materials. Diffraction and structure determination. Covers molecular geometry and levels of structure in biological materials. Includes experimental and computational exploration of the connections between structure, properties, processing, and performance of materials. Covers methodology of technical communication (written/oral) with a view to integrate experimental design, execution, and analysis.
C. A. Ross, R. Freitas

3.013 Mechanics of Materials
Prereq: Physics I (GIR) and *Coreq: 18.03*; or permission of instructor
U (Fall)
3-2-7 units

Basic concepts of solid mechanics and mechanical behavior of materials: elasticity, stress-strain relationships, stress transformation, viscoelasticity, plasticity, and fracture. Continuum behavior as well as atomistic explanations of the observed behavior are described. Examples from engineering as well as biomechanics. Lab experiments, computational exercises, and demonstrations give hands-on experience of the physical concepts.
C. Tasan

3.017 Modelling, Problem Solving, Computing, and Visualization
Prereq: ((3.030, 3.033, or 3.020) and (6.100A, 12.010, 16.66, or 3.016B)) or permission of instructor
U (Spring)
Not offered regularly; consult department
2-2-8 units

Covers development and design of models for materials processes and structure-property relations. Emphasizes techniques for solving equations from models or simulating their behavior. Assesses methods for visualizing solutions and aesthetics of the graphical presentation of results. Topics include symmetry and structure, classical and statistical thermodynamics, solid state physics, mechanics, phase transformations and kinetics, statistics and presentation of data.
W. C. Carter

3.019 Introduction to Symbolic and Mathematical Computing
Prereq: None
U (Fall)
Not offered regularly; consult department
2-1-0 units

Introduces fundamental computational techniques and applications of mathematics to prepare students for materials science and engineering curriculum. Covers elementary programming concepts, including data analysis and visualization. Students study computation/visualization and math techniques and apply them in computational software to gain familiarity with techniques used in subsequent subjects. Uses examples from material science and engineering applications, particularly from structure and mechanics of materials, including linear algebra, tensor transformations, review of calculus of several variables, numerical solutions to differential questions, and random walks.
W. C. Carter

3.020 Thermodynamics of Materials
Prereq: Chemistry (GIR); *Coreq: 18.03 or 18.032*
U (Spring)
4-2-6 units. REST

Introduces the competition between energetics and disorder that underpins materials thermodynamics. Presents classical thermodynamic concepts in the context of phase equilibria, including phase transformations, phase diagrams, and chemical reactions. Includes computerized thermodynamics and an introduction to statistical thermodynamics. Includes experimental and computational laboratories. Covers methodology of technical communication with the goal of presenting technical methods in broader contexts and for broad audiences.
R. Jaramillo, A. Gumyusenge

3.021 Introduction to Modeling and Simulation
Engineering School-Wide Elective Subject.
Offered under: 1.021, 3.021, 10.333, 22.00
Prereq: 18.03 or permission of instructor
U (Spring)
4-0-8 units. REST

Basic concepts of computer modeling and simulation in science and engineering. Uses techniques and software for simulation, data analysis and visualization. Continuum, mesoscale, atomistic and quantum methods used to study fundamental and applied problems in physics, chemistry, materials science, mechanics, engineering, and biology. Examples drawn from the disciplines above are used to understand or characterize complex structures and materials, and complement experimental observations.
M. Buehler

3.023 Synthesis and Design of Materials
Prereq: 3.010
U (Spring)
4-2-6 units

Provides understanding of transitions in materials, including intermolecular forces, self-assembly, physical organic chemistry, surface chemistry and electrostatics, hierarchical structure, and reactivity. Describes these fundamentals across classes of materials, including solid-state synthesis, polymer synthesis, sol-gel chemistry, and interactions with biological systems. Includes firsthand application of lecture topics through design-oriented experiments.
R. Macfarlane, A. Gumyusenge

3.029 Mathematics and Computational Thinking for Materials Scientists and Engineers I
Prereq: Calculus II (GIR); *Coreq: 3.020*
U (Spring)
3-0-9 units

Computational techniques and applications of mathematics to prepare students for a materials science and engineering curriculum. Students study computation/visualization and math techniques and apply them with symbolic algebra software (Mathematica). They code and visualize topics from symmetry and structure of materials and thermodynamics. Topics include symmetry and geometric transformations using linear algebra, review of calculus of several variables, numerical solutions to differential equations, tensor transformations, eigensystems, quadratic forms, and random walks. Supports concurrent material in 3.020.
W. C. Carter

3.030 Microstructural Evolution in Materials
Prereq: 3.010 and 3.020
U (Fall)
4-2-6 units

Covers microstructures, defects, and structural evolution in all classes of materials. Topics include solution kinetics, interface stability, dislocations and point defects, diffusion, surface energetics, grains and grain boundaries, grain growth, nucleation and precipitation, and electrochemical reactions. Lectures illustrate a range of examples and applications based on metals, ceramics, electronic materials, polymers, and biomedical materials. Explores the evolution of microstructure through experiments involving optical and electron microscopy, calorimetry, electrochemical characterization, surface roughness measurements, and other characterization methods. Investigates structural transitions and structure-property relationships through practical materials examples.
G. Beach

3.033 Electronic, Optical and Magnetic Properties of Materials
Prereq: 3.010 and 3.020
U (Fall)
4-2-6 units

Uses fundamental principles of quantum mechanics, solid state physics, electricity and magnetism to describe how the electronic, optical and magnetic properties of materials originate. Illustrates how these properties can be designed for particular applications, such as diodes, solar cells, optical fibers, and magnetic data storage. Involves experimentation using spectroscopy, resistivity, impedance and magnetometry measurements, behavior of light in waveguides, and other characterization methods. Uses practical examples to investigate structure-property relationships.
J. LeBeau

3.039 Mathematics and Computational Thinking for Materials Scientists and Engineers II
Prereq: 3.029; *Coreq: 3.030*
U (Fall)
Not offered regularly; consult department
3-0-6 units

Continues 3.029 with applications to microstructural evolution, electronic optical and magnetic properties of materials. Emphasizes and reinforces topics in 3.030 with visualization, computational, and mathematical techniques. Mathematics topics include symbolic and numerical solutions to partial differential equations, Fourier analysis, Bloch waves, and linear stability analysis.
W. C. Carter

3.041 Computational Materials Design
Subject meets with 3.321
Prereq: 3.013 and 3.030
U (Spring)
3-2-7 units

Systems approach to analysis and control of multilevel materials microstructures employing genomic fundamental databases. Applies quantitative process-structure-property-performance relations in computational parametric design of materials composition under processability constraints to achieve predicted microstructures meeting multiple property objectives established by industry performance requirements. Covers integration of macroscopic process models with microstructural simulation to accelerate materials qualification through component-level process optimization and forecasting of manufacturing variation to efficiently define minimum property design allowables. Case studies of interdisciplinary multiphysics collaborative modeling with applications across materials classes. Students taking graduate version complete additional assignments.
G. Olson

3.042 Materials Project Laboratory
Prereq: 3.030 or 3.033
U (Fall, Spring)
1-6-5 units

Serves as the capstone design course in the DMSE curriculum. Working in groups, students explore the research and design processes necessary to build prototype materials and devices. Instruction focuses on how to conceive, design, and execute a materials development research plan, on developing competence in the fundamental laboratory and materials processing skills introduced in earlier course work, and on the preparation required for personal success in a team-based professional environment. Selected topics are covered in manufacturing, statistics, intellectual property, and ethics. Instruction and practice in oral and written communication provided. Limited to 25 due to space constraints.
M. Tarkanian

3.044 Materials Processing
Prereq: 3.010 and 3.030
U (Spring)
4-0-8 units

Introduction to materials processing science, with emphasis on heat transfer, chemical diffusion, and fluid flow. Uses an engineering approach to analyze industrial-scale processes, with the goal of identifying and understanding physical limitations on scale and speed. Covers materials of all classes, including metals, polymers, electronic materials, and ceramics. Considers specific processes, such as melt-processing of metals and polymers, deposition technologies (liquid, vapor, and vacuum), colloid and slurry processing, viscous shape forming, and powder consolidation.
E. Olivetti

3.046 Advanced Thermodynamics of Materials
Prereq: 3.020 or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-9 units

Explores equilibrium thermodynamics through its application to topics in materials science and engineering. Begins with a fast-paced review of introductory classical and statistical thermodynamics. Students select additional topics to cover; examples include batteries and fuel cells, solar photovoltaics, magnetic information storage, extractive metallurgy, corrosion, thin solid films, and computerized thermodynamics.
R. Jaramillo

3.052 Nanomechanics of Materials and Biomaterials
Prereq: 3.013 or permission of instructor
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Latest scientific developments and discoveries in the field of nanomechanics, i.e. the deformation of extremely tiny (10-9 meters) areas of synthetic and biological materials. Lectures include a description of normal and lateral forces at the atomic scale, atomistic aspects of adhesion, nanoindentation, molecular details of fracture, chemical force microscopy, elasticity of individual macromolecular chains, intermolecular interactions in polymers, dynamic force spectroscopy, biomolecular bond strength measurements, and molecular motors.
C. Ortiz

3.053[J] Molecular, Cellular, and Tissue Biomechanics
Same subject as 2.797[J], 6.4840[J], 20.310[J]
Subject meets with 2.798[J], 3.971[J], 6.4842[J], 10.537[J], 20.410[J]
Prereq: Biology (GIR) and 18.03
U (Spring)
4-0-8 units

See description under subject 20.310[J].
M. Bathe, K. Ribbeck, P. T. So

3.054 Cellular Solids: Structure, Properties, Applications
Subject meets with 3.36
Prereq: 3.013
U (Spring)
Not offered regularly; consult department
3-0-9 units

Discusses processing and structure of cellular solids as they are created from polymers, metals, ceramics, glasses, and composites; derivation of models for the mechanical properties of honeycombs and foams; and how unique properties of honeycombs and foams are exploited in applications such as lightweight structural panels, energy absorption devices, and thermal insulation. Covers applications of cellular solids in medicine, such as increased fracture risk due to trabecular bone loss in patients with osteoporosis, the development of metal foam coatings for orthopedic implants, and designing porous scaffolds for tissue engineering that mimic the extracellular matrix. Includes modelling of cellular materials applied to natural materials and biomimicking. Offers a combination of online and in-person instruction. Students taking graduate version complete additional assignments.
L. Gibson

3.055[J] Biomaterials Science and Engineering
Same subject as 20.363[J]
Subject meets with 3.963[J], 20.463[J]
Prereq: 20.110[J] or permission of instructor
U (Fall)
3-0-9 units

See description under subject 20.363[J].
D. Irvine, K. Ribbeck

3.056[J] Materials Physics of Neural Interfaces
Same subject as 9.67[J]
Subject meets with 3.64[J], 9.670[J]
Prereq: 3.033 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

Builds a foundation of physical principles underlying electrical, optical, and magnetic approaches to neural recording and stimulation. Discusses neural recording probes and materials considerations that influence the quality of the signals and longevity of the probes in the brain. Students then consider physical foundations for optical recording and modulation. Introduces magnetism in the context of biological systems. Focuses on magnetic neuromodulation methods and touches upon magnetoreception in nature and its physical limits. Includes team projects that focus on designing electrical, optical, or magnetic neural interface platforms for neuroscience. Concludes with an oral final exam consisting of a design component and a conversation with the instructor. Students taking graduate version complete additional assignments.
P. Anikeeva

3.063 Polymer Physics
Subject meets with 3.942, 10.568
Prereq: 3.010
U (Fall)
3-0-9 units

The mechanical, optical, electrical, and transport properties of polymers and other types of "soft matter" are presented with respect to the underlying physics and physical chemistry of polymers and colloids in solution, and solid states. Topics include how enthalpy and entropy determine conformation, molecular dimensions and packing of polymer chains and colloids and supramolecular materials. Examination of the structure of glassy, crystalline, and rubbery elastic states of polymers; thermodynamics of solutions, blends, crystallization; liquid crystallinity, microphase separation, and self-assembled organic-inorganic nanocomposites. Case studies of relationships between structure and function in technologically important polymeric systems. Students taking graduate version complete additional assignments.
A. Alexander-Katz, G. Rutledge

3.064 Polymer Engineering
Prereq: 3.013 and 3.044
U (Fall)
Not offered regularly; consult department
3-0-9 units

Overview of polymer material science and engineering. Treatment of physical and chemical properties, mechanical characterization, processing, and their control through inspired polymer material design.
Staff

3.07 Introduction to Ceramics
Prereq: (3.010 and 3.020) or permission of instructor
U (Spring)
3-0-9 units

Discusses structure-property relationships in ceramic materials. Includes hierarchy of structures from the atomic to microstructural levels. Defects and transport, solid-state electrochemical processes, phase equilibria, fracture and phase transformations are discussed in the context of controlling properties for various applications of ceramics. Numerous examples from current technology.
Y. Chiang

3.071 Amorphous Materials
Prereq: (3.030 and 3.033) or permission of instructor
U (Spring)
3-0-9 units

Discusses the fundamental material science behind amorphous solids (non-crystalline materials). Covers formation of amorphous solids; amorphous structures and their electrical and optical properties; and characterization methods and technical applications.
J. Hu

3.074 Imaging of Materials
Subject meets with 3.34
Prereq: 3.033
U (Spring)
3-0-9 units

Principles and applications of (scanning) transmission electron microscopy. Topics include electron optics and aberration correction theory; modeling and simulating the interactions of electrons with the specimen; electron diffraction; image formation in transmission and scanning transmission electron microscopy; diffraction and phase contrast; imaging of crystals and crystal imperfections; review of the most recent advances in electron microscopy for bio- and nanosciences; analysis of chemical composition and electronic structure at the atomic scale. Lectures complemented by real-case studies and computer simulations/data analysis. Students taking graduate version complete additional assignments.
J. LeBeau

3.080 Strategic Materials Selection
Prereq: (3.010 and 3.020) or permission of instructor
Acad Year 2024-2025: U (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units

Provides a survey of methods for evaluating choice of material and explores the implications of that choice along economic and environmental dimensions. Topics include life cycle assessment, data uncertainty, manufacturing economics and utility analysis. Students carry out a group project selecting materials technology options based on performance characteristics beyond and including technical ones.
R. Kirchain, E. Olivetti

3.081 Industrial Ecology of Materials
Subject meets with 3.560
Prereq: (3.010 and 3.020) or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

Covers quantitative techniques to address principles of substitution, dematerialization, and waste mining implementation in materials systems. Includes life-cycle and materials flow analysis of the impacts of materials extraction; processing; use; and recycling for materials, products, and services. Student teams undertake a case study regarding materials and technology selection using the latest methods of analysis and computer-based models of materials process. Students taking graduate version complete additional assignments.
E. Olivetti

3.085[J] Venture Engineering
Same subject as 2.912[J], 15.373[J]
Prereq: None
U (Spring)
3-0-9 units

See description under subject 15.373[J].
S. Stern, E. Fitzgerald

3.086 Innovation and Commercialization of Materials Technology
Subject meets with 3.207
Prereq: None
U (Spring)
4-0-8 units

Introduces the fundamental process of innovating and its role in promoting growth and prosperity. Exposes students to innovation through team projects as a structured process, while developing skills to handle multiple uncertainties simultaneously. Provides training to address these uncertainties through research methods in the contexts of materials technology development, market applications, industry structure, intellectual property, and other factors. Case studies place the project in a context of historical innovations with worldwide impact. Combination of projects and real-world cases help students identify how they can impact the world through innovation.
E. Fitzgerald

3.087 Materials, Societal Impact, and Social Innovation
Prereq: 1.050, 2.001, 10.467, (3.010 and 3.020), or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

Students work on exciting, team-based projects at the interdisciplinary frontiers of materials research within a societal and humanistic context. Includes topics such as frontier research and inquiry, social innovation, human-centered design thinking, computational design, and additive manufacturing.
C. Ortiz, E. Spero

3.088 The Social Life of Materials
Subject meets with EC.988
Prereq: 1.050, 2.001, 3.010, 10.467, 20.310[J], or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-0-9 units

Students carry out projects on a material of their choice and study its technical, humanistic, and environmental origins and trajectories of development through historical methods; evaluate its current status within a social and humanistic context; and then imagine and evaluate potential futures. Projects supported by topics and scholarship in sociotechnical systems, social innovation, environmental history and justice, equity-based human-centered design, and futures literacy. Students taking the graduate version complete additional assignments.
C. Ortiz, E. Spero

3.091 Introduction to Solid-State Chemistry
Prereq: None
U (Fall, Spring)
5-0-7 units. CHEMISTRY
Credit cannot also be received for 5.111, 5.112, CC.5111, ES.5111, ES.5112

Basic principles of chemistry and their application to engineering systems. The relationship between electronic structure, chemical bonding, and atomic order. Characterization of atomic arrangements in crystalline and amorphous solids: metals, ceramics, semiconductors, and polymers. Topical coverage of organic chemistry, solution chemistry, acid-base equilibria, electrochemistry, biochemistry, chemical kinetics, diffusion, and phase diagrams. Examples from industrial practice (including the environmental impact of chemical processes), from energy generation and storage (e.g., batteries and fuel cells), and from emerging technologies (e.g., photonic and biomedical devices).
P. Anikeeva, R. Gomez-Bombarelli, K. Kolenbrander

3.093 Metalsmithing: Objects and Power (New)
Prereq: None
U (Fall)
1-5-3 units. HASS-A

Introduces traditional metalsmithing techniques to students in a studio environment. Project-based coursework investigates metalsmithing through the convergent lenses of art, science, and spirituality. Focuses on hand-crafted metal objects as historical signifiers of cultural values, power, and protection. Projects may include silver soldering, sawing and piercing, etching, casting, embossing, steel tool making, hollowware, and chasing and repousse. Limited to 9 due to space and equipment constraints.
R. Vedro

3.094[J] Materials in Human Experience
Same subject as 1.034[J]
Prereq: None
U (Spring)
2-3-4 units. HASS-S

Examines how people throughout history have selected, evaluated, processed, and utilized natural materials to create objects of material culture. Explores ideological and aesthetic criteria influential in materials development. As examples of ancient engineering and materials processing, topics may include ancient Roman concrete and prehistoric iron and steel production by the Mossi, Haya, and other African cultures. Particular attention paid to the climate issues surrounding iron and cement, and how the examination of ancient technologies can inform our understanding of sustainability in the present and illuminate paths for the future. Previous topics have included Maya use of lime plaster for frescoes, books, and architectural sculpture; the sound, color, and power of metals in Mesoamerica; and metal, cloth, and fiber technologies in the Inca empire. Laboratory sessions provide practical experience with materials discussed in class. Enrollment limited to 24.
M. Tarkanian, A. Masic

3.095 Introduction to Metalsmithing
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
2-3-4 units. HASS-A

Exploration of metal arts, design principles, sculptural concepts, and metallurgical processes. Covers traditional fine metalsmithing techniques including soldering, casting, and forming. Students create artworks that interpret lecture material and utilize metalsmithing as a means of expression. Engages a material culture lens to explore ideas of value, aesthetics, and meaning through object-making. Supplemented by visiting artist lectures and arts sector field trips. Limited to 9.
R. Vedro

3.096 Architectural Ironwork
Prereq: None
U (Fall)
2-3-4 units. HASS-A

Explores the use of iron in the built environment throughout history and the world, with an emphasis on traditional European and American design and connections to contemporary movements in art and architecture. Discusses influence of technology on design and fabrication, spanning both ancient and modern developments. Cultivates the ability to design iron in architecture and criticize ironwork as art. Includes laboratory exercises that teach a variety of basic and advanced iron-working techniques such as hand forging and CNC machining. The project-based curriculum begins with art criticism of Cambridge-area ironwork, progresses to practical studies of iron architectural elements, and finishes with creation of an architectural object of the student's design. Associated writing assignments for in-lab projects hone criticism and analysis skills. Limited to 6.
J. Hunter

3.098 Ancient Engineering: Ceramic Technologies
Subject meets with 3.991
Prereq: None
U (Fall)
3-0-9 units. HASS-S

Explores human interaction with ceramic materials over a considerable span of time, from 25,000 years ago to the 16th century AD. Through the lens of modern materials science combined with evidence from archaeological investigations, examines ancient ceramic materials — from containers to architecture to art — to better understand our close relationship with this important class of material culture. Examines ceramics structure, properties, and processing. Introduces archaeological perspectives and discusses how research into historical changes in ancient ceramic technologies has led to a deeper comprehension of past human behavior and societal development. Concludes by considering how studies of ancient technologies and techniques are leading modern materials scientists to engineer designs of modern ceramic materials, including glasses, concretes, and pigments. Students taking graduate version complete additional assignments.
J. Meanwell, W. Gilstrap

3.14 Modern Physical Metallurgy
Subject meets with 3.40[J], 22.71[J]
Prereq: 3.013; *Coreq: 3.030 or permission of instructor*
U (Fall)
3-0-9 units

Focuses on the links between the processing, structure, and properties of metals and alloys. First, the physical bases for strength, stiffness, and ductility are discussed with reference to crystallography, defects, and microstructure. Second, phase transformations and microstructural evolution are studied in the context of alloy thermodynamics and kinetics. Together, these components comprise the modern paradigm for designing metallic microstructures for optimized properties. Concludes with a focus on processing-microstructure-property relationships in structural engineering alloys. Students taking the graduate version explore the subject in greater depth.
R. Freitas

3.15 Electrical, Optical, and Magnetic Materials and Devices
Prereq: 3.033
U (Spring)
3-0-9 units

Explores the relationships between the performance of electrical, optical, and magnetic devices and the microstructural and defect characteristics of the materials from which they are constructed. Features a device-motivated approach that places strong emphasis on the design of functional materials for emerging technologies. Applications center around diodes, transistors, memristors, batteries, photodetectors, solar cells (photovoltaics) and solar-to-fuel converters, displays, light emitting diodes, lasers, optical fibers and optical communications, photonic devices, magnetic data storage and spintronics.
K. Kolenbrander

3.152 Magnetic Materials
Subject meets with 3.45
Prereq: 3.033
U (Spring)
3-0-9 units

Topics include origin of magnetism in materials, magnetic domains and domain walls, magnetostatics, magnetic anisotropy, antiferro- and ferrimagnetism, magnetism in thin films and nanoparticles, magnetotransport phenomena, and magnetic characterization. Discusses a range of applications, including magnetic recording, spin-valves, and tunnel-junction sensors. Assignments include problem sets and a term paper on a magnetic device or technology. Students taking graduate version complete additional assignments.
C. Ross

3.154[J] Materials Performance in Extreme Environments
Same subject as 22.054[J]
Prereq: 3.013 and 3.044
U (Spring)
Not offered regularly; consult department
3-2-7 units

Studies the behavior of materials in extreme environments typical of those in which advanced energy systems (including fossil, nuclear, solar, fuel cells, and battery) operate. Takes both a science and engineering approach to understanding how current materials interact with their environment under extreme conditions. Explores the role of modeling and simulation in understanding material behavior and the design of new materials. Focuses on energy and transportation related systems.
Staff

3.155[J] Micro/Nano Processing Technology
Same subject as 6.2600[J]
Prereq: Calculus II (GIR), Chemistry (GIR), Physics II (GIR), or permission of instructor
U (Spring)
3-4-5 units

See description under subject 6.2600[J]. Enrollment limited.
J. del Alamo, J. Michel, J. Scholvin

3.156 Photonic Materials and Devices
Subject meets with 3.46
Prereq: 3.033 and (18.03 or 3.016B)
U (Fall)
3-0-9 units

Optical materials design for semiconductors, dielectrics, organic and nanostructured materials. Ray optics, electromagnetic optics and guided wave optics. Physics of light-matter interactions. Device design principles: LEDs, lasers, photodetectors, solar cells, modulators, fiber and waveguide interconnects, optical filters, and photonic crystals. Device processing: crystal growth, substrate engineering, thin film deposition, etching and process integration for dielectric, silicon and compound semiconductor materials. Micro- and nanophotonic systems. Organic, nanostructured and biological optoelectronics. Assignments include three design projects that emphasize materials, devices and systems applications. Students taking graduate version complete additional assignments.
J. Hu

3.157 Organic Electronic Materials and Devices (New)
Prereq: 3.023 or permission of instructor
U (Fall)
3-0-9 units

Covers fundamentals of organic semiconductors and electronic devices made thereof. Introduces the emerging needs for soft-matter-based electronics and their applications in medical devices, sensors, and bioelectronics. Topics specific to organic semiconductors include molecular orbitals and band theory, synthesis and processing, energy levels and doping, photophysics, microstructure engineering and characterization, structure-property relationships, and charge transport. Device structures include organic thin-film transistors (OTFTs), organic light-emitting diodes (OLEDs), and organic photovoltaics (OPVs).
A. Gumyusenge

3.16 Industrial Challenges in Metallic Materials Selection
Subject meets with 3.39
Prereq: (3.010 and 3.020) or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

Advanced metals and alloy design with emphasis in advanced steels and non-ferrous alloys. Applies physical metallurgy concepts to solve specific problems targeting sustainable, efficient and safer engineered solutions. Discusses industrial challenges involving metallic materials selection and manufacturing for different value chains and industrial segments. Includes applications in essential segments of modern life, such as transportation, energy and structural applications. Recognizing steel as an essential engineering material, subject covers manufacturing and end-uses of advanced steels ranging from microalloyed steels to highly alloyed steels. Also covers materials for very low temperature applications such as superconducting materials and for higher temperature applications such as superalloys. Students taking graduate version complete additional assignments.
Staff

3.17 Principles of Manufacturing
Subject meets with 3.37
Prereq: 3.010 and 3.020
U (Fall)
2-1-9 units

Teaches the methodology to achieve Six Sigma materials yield: 99.99966% of end products perform within the required tolerance limits. Six Sigma methodology employs five stages for continuous improvement — problem definition, quantification, root cause analysis, solution implementation, and process control to help engineers evaluate efficiency and assess complex systems. Through case studies, explores classic examples of materials processing problems and the solutions that achieved Six Sigma manufacturing yield throughout the manufacturing system: extraction, design, unit processes, process flow, in-line control, test, performance/qualification, reliability, environmental impact, product life cycle, cost, and workforce. Students taking graduate version complete additional assignments.
L. C. Kimerling

3.171 Structural Materials and Manufacturing
Prereq: (3.010 and 3.020) or permission of instructor
U (Fall, Summer)
3-0-9 units
Credit cannot also be received for 2.821[J], 3.371[J]

Examines theoretical and practical aspects of structural materials by discussing mechanical properties of materials and manufacturing processes used to convert raw materials into high performance and reliable components for particular applications. Discusses specific types of steel, aluminum, titanium, ceramics, cement, polymers, and composites in context of commercially available product designations and specifications. Examines manufacturing processes used for exemplar products of each type of material, including heat treatments, sintering, and injection molding, among others. Considers established methods of metallurgical failure analysis and fractography through product failure case studies in order to prepare students to determine root causes of component failures in the real world. Students taking graduate version submit additional work. Meets with 3.371[J] when offered concurrently.
D. Baskin

3.173 Computing Fabrics
Subject meets with 3.373
Prereq: 3.013 or permission of instructor
U (Spring)
2-4-6 units

Highlights connections between industrialization, products, and advances in fibers and fabrics. Discusses the evolution of technologies in their path from basic scientific research to scaled production and global markets, with the ultimate objective of identifying and investigating the degrees of freedom that make fabrics such a powerful form of synthetic engineering and product expression. Topics explored, in part through interactions with industry speakers, include: fiber, yarn, textiles and fabric materials, structure-property relations, and practical demonstrations to anticipate future textile products. Students taking graduate version complete additional assignments. Limited to 20.
Y. Fink

3.18 Materials Science and Engineering of Clean Energy
Subject meets with 3.70
Prereq: 3.030 and 3.033
U (Spring)
3-0-9 units

Develops the materials principles, limitations, and challenges of clean energy technologies, including solar, energy storage, thermoelectrics, fuel cells, and novel fuels. Draws correlations between the limitations and challenges related to key figures of merit and the basic underlying thermodynamic, structural, transport, and physical principles, as well as to the means for fabricating devices exhibiting optimum operating efficiencies and extended life at reasonable cost. Students taking graduate version complete additional assignments.
Staff

3.19 Sustainable Chemical Metallurgy
Subject meets with 3.50
Prereq: 3.030
U (Spring)
3-0-9 units

Covers principles of metal extraction processes. Provides a direct application of the fundamentals of thermodynamics and kinetics to the industrial production of metals from their ores, e.g., iron, aluminum, or reactive metals and silicon. Discusses the corresponding economics and global challenges. Addresses advanced techniques for sustainable metal extraction, particularly with respect to greenhouse gas emissions. Students taking graduate version complete additional assignments.
A. Allanore

3.20 Materials at Equilibrium
Prereq: (3.010, 3.013, 3.020, 3.023, 3.030, 3.033, and 3.042) or permission of instructor
G (Fall)
5-0-10 units

Laws of thermodynamics: general formulation and applications to mechanical, electromagnetic and electrochemical systems, solutions, and phase diagrams. Computation of phase diagrams. Statistical thermodynamics and relation between microscopic and macroscopic properties, including ensembles, gases, crystal lattices, phase transitions. Applications to phase stability and properties of mixtures. Representations of chemical equilibria. Interfaces.
A. Allanore

3.201 Introduction to DMSE
Prereq: Permission of instructor
G (Fall)
2-0-1 units

Introduces new DMSE graduate students to DMSE research groups and the departmental spaces available for research. Guides students in joining a research group. Registration limited to students enrolled in DMSE graduate programs.
R. Macfarlane

3.202 Essential Research Skills
Prereq: Permission of instructor
G (Spring)
2-0-1 units

Provides instruction in the planning, writing, literature review, presentation, and communication of advanced graduate research work. Registration limited to students enrolled in DMSE graduate programs.
C. Tasan

3.207 Innovation and Commercialization
Subject meets with 3.086
Prereq: None
G (Spring)
4-0-8 units

Explores in depth projects on a particular materials-based technology. Investigates the science and technology of materials advances and their strategic value, explore potential applications for fundamental advances, and determine intellectual property related to the materials technology and applications. Students map progress with presentations, and are expected to create an end-of-term document enveloping technology, intellectual property, applications, and potential commercialization. Lectures cover aspects of technology, innovation, entrepreneurship, intellectual property, and commercialization of fundamental technologies.
E. Fitzgerald

3.21 Kinetic Processes in Materials
Prereq: 3.030, 3.044, (3.010 and 3.020), or permission of instructor
G (Spring)
5-0-10 units

Unified treatment of phenomenological and atomistic kinetic processes in materials. Provides the foundation for the advanced understanding of processing, microstructural evolution, and behavior for a broad spectrum of materials. Topics include irreversible thermodynamics; rate and transition state theory, diffusion; nucleation and phase transitions; continuous phase transitions; grain growth and coarsening; capillarity driven morphological evolution; and interface stability during phase transitions.
C. Thompson, M. Cima

3.22 Structure and Mechanics of Materials
Prereq: 3.013 or permission of instructor
G (Fall)
4-0-8 units

Explores structural characteristics of materials focusing on bonding types, crystalline and non-crystalline states, molecular and polymeric materials, and nano-structured materials. Discusses how the macroscale mechanical response of materials, and micro-mechanisms of elasticity, plasticity, and fracture, originate from these structural characteristics. Case studies and examples are drawn from a variety of material classes: metals, ceramics, polymers, thin films, composites, and cellular materials.
F. M. Ross

3.23 Electrical, Optical, and Magnetic Properties of Materials
Prereq: 8.03 and 18.03
G (Spring)
4-0-8 units

Origin of electrical, magnetic and optical properties of materials. Focus on the acquisition of quantum mechanical tools. Analysis of the properties of materials. Presentation of the postulates of quantum mechanics. Examination of the hydrogen atom, simple molecules and bonds, and the behavior of electrons in solids and energy bands. Introduction of the variation principle as a method for the calculation of wavefunctions. Investigation of how and why materials respond to different electrical, magnetic and electromagnetic fields and probes. Study of the conductivity, dielectric function, and magnetic permeability in metals, semiconductors, and insulators. Survey of common devices such as transistors, magnetic storage media, optical fibers.
G. Beach

3.30[J] Properties of Solid Surfaces
Same subject as 22.75[J]
Prereq: 3.20, 3.21, or permission of instructor
G (Spring)
3-0-9 units

See description under subject 22.75[J].
B. Yildiz

3.31[J] Radiation Damage and Effects in Nuclear Materials
Same subject as 22.74[J]
Subject meets with 22.074
Prereq: 3.21, 22.14, or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

See description under subject 22.74[J].
M. Short, B. Yildiz

3.320 Atomistic Computer Modeling of Materials
Prereq: 3.030, 3.20, 3.23, or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Theory and application of atomistic computer simulations to model, understand, and predict the properties of real materials. Energy models: from classical potentials to first-principles approaches. Density-functional theory and the total-energy pseudopotential method. Errors and accuracy of quantitative predictions. Thermodynamic ensembles: Monte Carlo sampling and molecular dynamics simulations. Free energies and phase transitions. Fluctations and transport properties. Coarse-graining approaches and mesoscale models.
Staff

3.321 Computational Materials Design
Subject meets with 3.041
Prereq: 3.20
G (Spring)
3-2-7 units

Systems approach to analysis and control of multilevel materials microstructures employing genomic fundamental databases. Applies quantitative process-structure-property-performance relations in computational parametric design of materials composition under processability constraints to achieve predicted microstructures meeting multiple property objectives established by industry performance requirements. Covers integration of macroscopic process models with microstructural simulation to accelerate materials qualification through component-level process optimization and forecasting of manufacturing variation to efficiently define minimum property design allowables. Case studies of interdisciplinary multiphysics collaborative modeling with applications across materials classes. Students taking graduate version complete additional assignments.
G. Olson

3.33[J] Defects in Materials
Same subject as 22.73[J]
Prereq: 3.21 and 3.22
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Examines point, line, and planar defects in structural and functional materials. Relates their properties to transport, radiation response, phase transformations, semiconductor device performance and quantum information processing. Focuses on atomic and electronic structures of defects in crystals, with special attention to optical properties, dislocation dynamics, fracture, and charged defects population and diffusion. Examples also drawn from other systems, e.g., disclinations in liquid crystals, domain walls in ferromagnets, shear bands in metallic glass, etc.
J. Li

3.34 Imaging of Materials
Subject meets with 3.074
Prereq: 3.033, 3.23, or permission of instructor
G (Spring)
3-0-9 units

Principles and applications of (scanning) transmission electron microscopy. Topics include electron optics and aberration correction theory; modeling and simulating the interactions of electrons with the specimen; electron diffraction; image formation in transmission and scanning transmission electron microscopy; diffraction and phase contrast; imaging of crystals and crystal imperfections; review of the most recent advances in electron microscopy for bio- and nanosciences; analysis of chemical composition and electronic structure at the atomic scale. Lectures complemented by real-case studies and computer simulations/data analysis. Students taking graduate version complete additional assignments.
J. LeBeau

3.35 Fracture and Fatigue
Prereq: 3.22 or permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Advanced study of material failure in response to mechanical stresses. Damage mechanisms include microstructural changes, crack initiation, and crack propagation under monotonic and cyclic loads. Covers a wide range of materials: metals, ceramics, polymers, thin films, biological materials, composites. Describes toughening mechanisms and the effect of material microstructures. Includes stress-life, strain-life, and damage-tolerant approaches. Emphasizes fracture mechanics concepts and latest applications for structural materials, biomaterials, microelectronic components as well as nanostructured materials. Limited to 10.
M. Dao

3.36 Cellular Solids: Structure, Properties, Applications
Subject meets with 3.054
Prereq: 3.013 or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Discusses processing and structure of cellular solids as they are created from polymers, metals, ceramics, glasses, and composites; derivation of models for the mechanical properties of honeycombs and foams; and how unique properties of honeycombs and foams are exploited in applications such as lightweight structural panels, energy absorption devices, and thermal insulation. Covers applications of cellular solids in medicine, such as increased fracture risk due to trabecular bone loss in patients with osteoporosis, the development of metal foam coatings for orthopedic implants, and designing porous scaffolds for tissue engineering that mimic the extracellular matrix. Includes modelling of cellular materials applied to natural materials and biomimicking. Offers a combination of online and in-person instruction. Students taking graduate version complete additional assignments.
L. Gibson

3.37 Principles of Manufacturing
Subject meets with 3.17
Prereq: None
G (Fall)
2-1-9 units

Teaches the methodology to achieve Six Sigma materials yield: 99.99966% of end products perform within the required tolerance limits. Six Sigma methodology employs five stages for continuous improvement — problem definition, quantification, root cause analysis, solution implementation, and process control to help engineers evaluate efficiency and assess complex systems. Through case studies, explores classic examples of materials processing problems and the solutions that achieved Six Sigma manufacturing yield throughout the manufacturing system: extraction, design, unit processes, process flow, in-line control, test, performance/qualification, reliability, environmental impact, product life cycle, cost, and workforce. Students taking graduate version complete additional assignments.
L. C. Kimerling

3.371[J] Structural Materials
Same subject as 2.821[J]
Prereq: Permission of instructor
G (Fall, Summer)
3-0-9 units
Credit cannot also be received for 3.171

Examines theoretical and practical aspects of structural materials by discussing mechanical properties of materials and manufacturing processes used to convert raw materials into high performance and reliable components for particular applications. Discusses specific types of steel, aluminum, titanium, ceramics, cement, polymer,s and composites in context of commercially available product designations and specifications. Examines manufacturing processes used for exemplar products of each type of material, such as heat treatments, sintering, and injection molding, among others. Considers established methods of metallurgical failure analysis and fractography through product failure case studies in order to prepare students to determine root causes of component failures in the real world. Students taking graduate version submit additional work. Meets with 3.171 when offered concurrently.
D. Baskin

3.373 Computing Fabrics
Subject meets with 3.173
Prereq: None
G (Spring)
2-4-6 units

Highlights connections between industrialization, products, and advances in fibers and fabrics. Discusses the evolution of technologies in their path from basic scientific research to scaled production and global markets, with the ultimate objective of identifying and investigating the degrees of freedom that make fabrics such a powerful form of synthetic engineering and product expression. Topics explored, in part through interactions with industry speakers, include: fiber, yarn, textiles and fabric materials, structure-property relations, and practical demonstrations to anticipate future textile products. Students taking graduate version complete additional assignments. Limited to 20.
Y. Fink

3.39 Industrial Challenges in Metallic Materials Selection
Subject meets with 3.16
Prereq: 3.20 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Advanced metals and alloy design with emphasis in advanced steels and non-ferrous alloys. Applies physical metallurgy concepts to solve specific problems aiming at sustainable, efficient and safer engineered solutions. Discusses industrial challenges involving metallic materials selection and manufacturing for different value chains and industrial segments. Includes applications in essential segments of modern life such as transportation, energy and strutuctural applications. Recognizing steel as an essential engineering material, the course will cover manufacturing and end-uses of advanced steels ranging from microalloyed steels to highly alloyed steels. Materials for very low temperature applications such as superconducting materials and for higher temperature applications such as superalloys will also be covered. Students taking graduate version complete additional assignments.
Staff

3.40[J] Modern Physical Metallurgy
Same subject as 22.71[J]
Subject meets with 3.14
Prereq: (3.20 and 3.22) or permission of instructor
G (Fall)
3-0-9 units

Focuses on the links between the processing, structure, and properties of metals and alloys. First, the physical bases for strength, stiffness, and ductility are discussed with reference to crystallography, defects, and microstructure. Second, phase transformations and microstructural evolution are studied in the context of alloy thermodynamics and kinetics. Together, these components comprise the modern paradigm for designing metallic microstructures for optimized properties. Concludes with a focus on processing-microstructure-property relationships in structural engineering alloys. Students taking the graduate version explore the subject in greater depth.
R. Freitas

3.41 Colloids, Surfaces, Absorption, Capillarity, and Wetting Phenomena
Prereq: 3.20 and 3.21
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Integrates elements of physics and chemistry toward the study of material surfaces. Begins with classical colloid phenomena and the interaction between surfaces in different media. Discusses the mechanisms of surface charge generation as well as how dispersion forces are created and controlled. Continues with exploration of chemical absorption processes and surface design of inorganic and organic materials. Includes examples in which such surface design can be used to control critical properties of materials in applications. Addresses lastly how liquids interact with solids as viewed by capillarity and wetting phenomena. Studies how materials are used in processes and applications that are intended to control liquids, and how the surface chemistry and structure of those materials makes such applications possible.
M. Cima

3.42 Electronic Materials Design
Prereq: 3.23
G (Spring)
3-0-9 units

Extensive and intensive examination of structure-processing-property correlations for a wide range of materials including metals, semiconductors, dielectrics, and optical materials. Topics covered include defect equilibria; junction characteristics; photodiodes, light sources and displays; bipolar and field effect transistors; chemical, thermal and mechanical transducers; data storage. Emphasis on materials design in relation to device performance.
H. L. Tuller

3.43[J] Integrated Microelectronic Devices
Same subject as 6.6500[J]
Prereq: 3.42 or 6.2500
G (Fall)
4-0-8 units

See description under subject 6.6500[J].
J. A. del Alamo, H. L. Tuller

3.44 Materials Processing for Micro- and Nano-Systems
Prereq: 3.20 and 3.21
G (Fall)
3-0-9 units

Processing of bulk, thin film, and nanoscale materials for applications in electronic, magnetic, electromechanical, and photonic devices and microsystems. Topics include growth of bulk, thin-film, nanoscale single crystals via vapor and liquid phase processes; formation, patterning and processing of thin films, with an emphasis on relationships among processing, structure, and properties; and processing of systems of nanoscale materials. Examples from materials processing for applications in high-performance integrated electronic circuits, micro-/nano-electromechanical devices and systems and integrated sensors.
C. V. Thompson

3.45 Magnetic Materials
Subject meets with 3.152
Prereq: 3.23
G (Spring)
3-0-9 units

Topics include origin of magnetism in materials, magnetic domains and domain walls, magnetostatics, anisotropy, antiferro- and ferrimagnetism, magnetization dynamics, spintronics, magnetism in thin films and nanoparticles, magnetotransport phenomena, and magnetic characterization. Discusses a range of applications, including magnetic recording, spintronic memory, magnetoopical devices, and multiferroics. Assignments include problem sets and a term paper on a magnetic device or technology. Students taking graduate version complete additional assignments.
C. Ross

3.46 Photonic Materials and Devices
Subject meets with 3.156
Prereq: 3.23
G (Fall)
3-0-9 units

Optical materials design for semiconductors, dielectrics and polymers. Ray optics, electromagnetic optics and guided wave optics. Physics of light-matter interactions. Device design principles: LEDs, lasers, photodetectors, modulators, fiber and waveguide interconnects, optical filters, and photonic crystals. Device processing: crystal growth, substrate engineering, thin film deposition, etching and process integration for dielectric, silicon and compound semiconductor materials. Microphotonic integrated circuits. Telecom/datacom systems. Assignments include three design projects that emphasize materials, devices and systems applications. Students taking graduate version complete additional assignments.
J. Hu

3.48 Measurement Science for Materials Research
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
4-0-8 units

Covers essentials of measurement science, including instrumentation, instrument-computer interfacing, experimental design, calibration and systematic errors, measurement statistics, data representation, and elements of data analysis, including model selection and statistical analysis. Structured around a series of case studies chosen by the class. Options include: electrical and Hall conductivity measurements, semiconductor junction measurements, spectroscopy (including photoluminescence, Raman, and photoelectron), magnetometry, elemental composition analysis and depth profiling, atomic force microscopy, nanoindentation, dynamical correlations and related measurements, and measuring pressure (from ultra-high vacuum to megabar). Familiarity with coding and data analysis required. Specific measurement challenges in the students' own research discussed.
R. Jaramillo

3.50 Sustainable Chemical Metallurgy
Subject meets with 3.19
Prereq: 3.030 or permission of instructor
G (Spring)
3-0-9 units

Covers principles of metal extraction processes. Provides a direct application of the fundamentals of thermodynamics and kinetics to the industrial production of metals from their ores, e.g. iron, aluminum, or reactive metals and silicon. Discusses the corresponding economics and global challenges. Addresses advanced techniques for sustainable metal extraction, particularly with respect to greenhouse gas emissions. Students taking graduate version complete additional assignments.
A. Allanore

3.53 Electrochemical Processing of Materials
Prereq: 3.044
G (Spring)
Not offered regularly; consult department
3-0-6 units

Thermodynamic and transport properties of aqueous and nonaqueous electrolytes. The electrode/electrolyte interface. Kinetics of electrode processes. Electrochemical characterization: d.c. techniques (controlled potential, controlled current), a.c. techniques (voltametry and impedance spectroscopy). Applications: electrowinning, electrorefining, electroplating, and electrosynthesis, as well as electrochemical power sources (batteries and fuel cells).
Staff

3.55[J] Ionics and Its Applications
Same subject as 22.76[J]
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

See description under subject 22.76[J].
J. Li, B. Yildiz

3.560 Industrial Ecology of Materials
Subject meets with 3.081
Prereq: 3.20 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Covers quantitative techniques to address principles of substitution, dematerialization, and waste mining implementation in materials systems. Includes life-cycle and materials flow analysis of the impacts of materials extraction; processing; use; and recycling for materials, products, and services. Student teams undertake a case study regarding materials and technology selection using the latest methods of analysis and computer-based models of materials process. Students taking graduate version complete additional assignments.
E. Olivetti

3.57 Materials Selection, Design, and Economics
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-6 units

A survey of techniques for analyzing how the choice of materials, processes, and design determine properties, performance, and cost. Topics include production and cost functions, mathematical optimization, evaluation of single and multi-attribute utility, decision analysis, materials property charts, and performance indices. Students use analytical techniques to develop a plan for starting a new materials-related business.
Staff

3.64[J] Materials Physics of Neural Interfaces
Same subject as 9.670[J]
Subject meets with 3.056[J], 9.67[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Builds a foundation of physical principles underlying electrical, optical, and magnetic approaches to neural recording and stimulation. Discusses neural recording probes and materials considerations that influence the quality of the signals and longevity of the probes in the brain. Students then consider physical foundations for optical recording and modulation. Introduces magnetism in the context of biological systems. Focuses on magnetic neuromodulation methods and touches upon magnetoreception in nature and its physical limits. Includes team projects that focus on designing electrical, optical, or magnetic neural interface platforms for neuroscience. Concludes with an oral final exam consisting of a design component and a conversation with the instructor. Students taking graduate version complete additional assignments.
P. Anikeeva

3.65 Soft Matter Characterization
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

Focuses on the design and execution of advanced experiments to characterize soft materials, such as synthetic and natural polymers, biological composites, and supramolecular nanomaterials. Each week focuses on a new characterization technique explored through interactive lectures, demonstrations, and practicum sessions in which students gain experience in key experimental aspects of soft matter sample preparation and characterization. Among others, topics include chemical characterization, rheology and viscometry, microscopy, and spectroscopic analyses. Limited to 15.
Staff

3.69 Teaching Fellows Seminar
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
2-0-1 units
Can be repeated for credit.

Provides instruction to help prepare students for teaching at an advanced level and for industry or academic career paths. Topics include preparing a syllabus, selecting a textbook, scheduling assignments and examinations, lecture preparation, "chalk and talk" vs. electronic presentations, academic honesty and discipline, preparation of examinations, grading practices, working with teaching assistants, working with colleagues, mentoring outside the classroom, pursuing academic positions, teaching through technical talks, and successful grant writing strategies.
R. Macfarlane

3.691 Teaching Materials Science and Engineering
Prereq: Permission of instructor
U (Fall, Spring)
0-1-0 units
Can be repeated for credit.

Provides classroom or laboratory teaching experience under the supervision of faculty member(s). Students assist faculty by preparing instructional materials, leading discussion groups, and monitoring students' progress. Limited to Course 3 undergraduates selected by Teaching Assignments Committee.
J. Hu

3.692 Teaching Materials Science and Engineering
Prereq: Permission of instructor
U (Fall, Spring)
Units arranged
Can be repeated for credit.

Provides classroom or laboratory teaching experience under the supervision of faculty member(s). Students assist faculty by preparing instructional materials, leading discussion groups, and monitoring students' progress. Credit arranged on a case-by-case basis and reviewed by the department. Limited to Course 3 undergraduates selected by Teaching Assignments Committee.
J. Hu

3.694 Teaching Materials Science and Engineering
Prereq: None
G (Spring)
Units arranged
Can be repeated for credit.

Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview. Enrollment limited by availability of suitable teaching assignments.
Staff

3.693-3.699 Teaching Materials Science and Engineering
Prereq: None
G (IAP)
Units arranged
Can be repeated for credit.

Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview. Enrollment limited by availability of suitable teaching assignments.
D. Sadoway

3.70 Materials Science and Engineering of Clean Energy
Subject meets with 3.18
Prereq: 3.20, 3.23, or permission of instructor
G (Spring)
3-0-9 units

Develops the materials principles, limitations and challenges in clean energy technologies, including solar, energy storage, thermoelectrics, fuel cells, and novel fuels. Draws correlations between the limitations and challenges related to key figures of merit and the basic underlying thermodynamic, structural, transport, and physical principles, as well as to the means for fabricating devices exhibiting optimum operating efficiencies and extended life at reasonable cost. Students taking graduate version complete additional assignments.
Staff

3.903[J] Seminar in Polymers and Soft Matter
Same subject as 10.960[J]
Prereq: None
G (Fall, Spring)
2-0-0 units
Can be repeated for credit.

See description under subject 10.960[J].
A. Alexander-Katz, R. E. Cohen, D. Irvine

3.930 Internship Program
Prereq: None
U (Fall, Spring, Summer)
0-6-0 units

Provides academic credit for first approved materials science and engineering internship. For reporting requirements, consult the faculty internship program coordinator. Limited to Course 3 internship track majors.
A. Allanore

3.931 Internship Program
Prereq: 3.930
U (Fall, Spring, Summer)
0-6-0 units

Provides academic credit for second approved materials science and engineering internship in the year following completion of 3.930. For reporting requirements consult the faculty internship program coordinator. Limited to Course 3 internship track majors.
A. Allanore

3.932 Industrial Practice
Prereq: Permission of instructor
G (Summer)
Units arranged
Can be repeated for credit.

Provides academic credit to graduate students for approved internship assignments at companies/national laboratories. Restricted to DMSE SM or PhD/ScD students.
D. Sadoway

3.941[J] Statistical Mechanics of Polymers
Same subject as 10.668[J]
Prereq: 10.568 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

See description under subject 10.668[J].
G. C. Rutledge, A. Alexander-Katz

3.942 Polymer Physics
Subject meets with 3.063, 10.568
Prereq: 3.013 or permission of instructor
G (Fall)
3-0-9 units

The mechanical, optical, electrical, and transport properties of polymers and other types of "soft matter" are presented with respect to the underlying physics and physical chemistry of polymers and colloids in solution, and solid states. Topics include how enthalpy and entropy determine conformation, molecular dimensions and packing of polymer chains and colloids and supramolecular materials. Examination of the structure of glassy, crystalline, and rubbery elastic states of polymers; thermodynamics of solutions, blends, crystallization; liquid crystallinity, microphase separation, and self-assembled organic-inorganic nanocomposites. Case studies of relationships between structure and function in technologically important polymeric systems. Students taking graduate version complete additional assignments.
A. Alexander-Katz, G. Rutledge

3.963[J] Biomaterials Science and Engineering
Same subject as 20.463[J]
Subject meets with 3.055[J], 20.363[J]
Prereq: 20.110[J] or permission of instructor
G (Fall)
3-0-9 units

See description under subject 20.463[J].
D. Irvine, K. Ribbeck

3.971[J] Molecular, Cellular, and Tissue Biomechanics
Same subject as 2.798[J], 6.4842[J], 10.537[J], 20.410[J]
Subject meets with 2.797[J], 3.053[J], 6.4840[J], 20.310[J]
Prereq: Biology (GIR) and 18.03
G (Spring)
3-0-9 units

See description under subject 20.410[J].
M. Bathe, K. Ribbeck, P. T. So

Archaeology and Archaeological Science

3.981 Communities of the Living and the Dead: the Archaeology of Ancient Egypt
Prereq: None
U (Spring)
Not offered regularly; consult department
3-0-9 units. HASS-S

Examines the development of complex societies in Egypt over a 3000-year period. Uses archaeological and historical sources to determine how and why prehistoric communities coalesced into a long-lived and powerful state. Studies the remains of ancient settlements, tombs, and temples, exploring their relationships to one another and to the geopolitical landscape of Egypt and the Mediterranean world. Considers the development of advanced technologies, rise of social hierarchy, expansion of empire, role of writing, and growth of a complex economy.
Staff

3.982 The Ancient Andean World
Prereq: None
U (Fall)
Not offered regularly; consult department
3-0-6 units. HASS-S

Examines development of Andean civilization which culminated in the extraordinary empire established by the Inka. Archaeological, ethnographic, and ethnohistorical approaches. Particular attention to the unusual topography of the Andean area, its influence upon local ecology, and the characteristic social, political, and technological responses of Andean people to life in a topographically "vertical" world. Characteristic cultural styles of prehistoric Andean life.
Staff

3.983 Ancient Mesoamerican Civilization
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-6 units. HASS-S

Examines origins, florescence and collapse of selected civilizations of ancient Mesoamerica using archaeological and ethnohistoric evidence. Focuses on the Maya, including their hieroglyphic writing. Themes include development of art and architecture, urbanism, religious and political institutions, human-environment interactions, and socio-political collapse. Representations of Maya society in contemporary film and media. Limited to 10.
F. Rossi

3.984 Materials in Ancient Societies I
Prereq: Permission of instructor
G (Fall)
3-6-3 units

Seminars and labs provide in-depth study of the technologies ancient societies used to produce objects from raw materials. Seminars cover basic materials science and engineering concepts and techniques that can be used to understand how materials were produced and used in the past. The materials selection and processing are then linked to the environment, exchange, political power, and cultural values. The specific material covered each year rotates and may include ceramics, metals, stone, glass, or bones/organic materials. Contact the instructor for more information about the material covered each year.
A. Allanore, J. Meanwell, W. Gilstrap

3.985[J] Archaeological Science
Same subject as 5.24[J], 12.011[J]
Prereq: Chemistry (GIR) or Physics I (GIR)
U (Spring)
3-1-5 units. HASS-S

Pressing issues in archaeology as an anthropological science. Stresses the natural science and engineering methods archaeologists use to address these issues. Reconstructing time, space, and human ecologies provides one focus; materials technologies that transform natural materials to material culture provide another. Topics include 14C dating, ice core and palynological analysis, GIS and other remote sensing techniques for site location, organic residue analysis, comparisons between Old World and New World bronze production, invention of rubber by Mesoamerican societies, analysis and conservation of Dead Sea Scrolls.
M. Tarkanian, J. Meanwell

3.986[J] The Human Past: Introduction to Archaeology
Same subject as 21A.503[J]
Prereq: None
U (Fall)
3-0-9 units. HASS-S; CI-H

From an archaeological perspective, examines ancient human activities and the forces that shaped them. Draws on case studies from the Old and/or New World. Exposes students to various classes of archaeological data, such as stone, bone, and ceramics, that help reconstruct the past.
F. Rossi

3.987 Human Evolution: Data from Palaeontology, Archaeology, and Materials Science
Prereq: None
U (Spring)
3-2-7 units. HASS-S

Examines human physical and cultural evolution over the past five million years via lectures and labs that incorporate data from human palaeontology, archaeology, and materials science. Topics include the evolution of hominin morphology and adaptations; the nature and structure of bone and its importance in human evolution; and the fossil and archaeological evidence for human behavioral and cultural evolution, from earliest times through the Pleistocene. Laboratory sessions include study of stone technology, artifacts, and fossil specimens.
F. Rossi

3.988 Maya City Building: Materials, Technology, and Ecology in an Ancient Society
Prereq: None
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units. HASS-S

Explores relationship between archaeology and materials science, and the potential to methodologically connect these fields. Taking ancient Maya society as an archaeological case study, surveys 13 materials utilized by Indigenous Maya peoples before European contact. Focuses on the modes of materials analysis used in archaeology, as well as experimental methods in which ancient technologies are replicated and approached as windows into human social, political and economic systems. In dialogue with community archaeology, class discussions and material explorations are shaped by questions offered by Maya craftspeople and descendent communities of experts today.
F. Rossi

3.989 Materials in Ancient Societies II
Prereq: 3.984 or permission of instructor
G (Spring)
3-6-3 units

Additional seminars and laboratory analysis of archaeological artifacts. Seminars cover broader archaeological questions related to human/material interactions. Builds on 3.984.
A. Allanore, J. Meanwell, W. Gilstrap

3.990 Seminar in Archaeological Method and Theory
Prereq: 3.985[J], 3.986[J], and 21A.00
U (Spring)
3-0-6 units

Designed for undergraduate seniors majoring in Archaeology and Materials. Critical analysis of major intellectual and methodological developments in American archaeology, including evolutionary theory, the "New Archaeology," Marxism, formal and ideological approaches. Explores the use of science and engineering methods to reconstruct cultural patterns from archaeological data. Seminar format, with formal presentations by all students. Non-majors fulfilling all prerequisites may enroll by permission of instructors. Instruction and practice in oral and written communication provided.
Staff

3.991 Ancient Engineering: Ceramic Technologies
Subject meets with 3.098
Prereq: None
G (Fall)
3-0-9 units

Explores human interaction with ceramic materials over a considerable span of time, from 25,000 years ago to the 16th century AD. Through the lens of modern materials science combined with evidence from archaeological investigations, examines ancient ceramic materials — from containers to architecture to art — to better understand our close relationship with this important class of material culture. Examines ceramics structure, properties, and processing. Introduces archaeological perspectives and discusses how research into historical changes in ancient ceramic technologies has led to a deeper comprehension of past human behavior and societal development. Concludes by considering how studies of ancient technologies and techniques are leading modern materials scientists to engineer designs of modern ceramic materials, including glasses, concretes, and pigments. Students taking graduate version complete additional assignments.
J. Meanwell, W. Gilstrap

3.993 Archaeology of the Middle East
Prereq: None
U (Spring)
3-0-6 units. HASS-S

Explores the long history of the Middle East and its role as an enduring center of civilization and human thought. Beginning over 100,000 years ago and ending up in the present day, tackles major issues in the human career through examination of archaeological and written materials. Students track the course of human development in the Middle East, from hunting and gathering to cities and empires.
Staff

3.995 First Year Thesis Research
Prereq: None. *Coreq: 3.202*; permission of instructor
G (Spring)
Units arranged [P/D/F]

Preparation for program of research leading to the writing of an SM, PhD, or ScD thesis; to be arranged by the student and an appropriate MIT faculty member. Includes research presentation, in coordination with 3.202.
R. Macfarlane

3.997 Graduate Fieldwork in Materials Science and Engineering
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.

Program of field research in materials science and engineering leading to the writing of an SM, PhD, or ScD thesis; to be arranged by the student and an appropriate MIT faculty member.
Staff

3.998 Doctoral Thesis Update Meeting
Prereq: None
G (Fall, Spring)
0-1-0 units

Thesis research update presentation to the thesis committee. Held the first or second academic term after successfully passing the Thesis Area Examination.
Staff

3.C01[J] Machine Learning for Molecular Engineering
Same subject as 10.C01[J], 20.C01[J]
Subject meets with 3.C51[J], 7.C01, 7.C51, 10.C51[J], 20.C51[J]
Prereq: Calculus II (GIR) and 6.100A; *Coreq: 6.C01*
U (Spring)
2-0-4 units
Credit cannot also be received for 1.C01, 1.C51, 2.C01, 2.C51, 3.C51[J], 7.C01, 7.C51, 10.C51[J], 20.C51[J], 22.C01, 22.C51, SCM.C51

Building on core material in 6.C01, provides an introduction to the use of machine learning to solve problems arising in the science and engineering of biology, chemistry, and materials. Equips students to design and implement machine learning approaches to challenges such as analysis of omics (genomics, transcriptomics, proteomics, etc.), microscopy, spectroscopy, or crystallography data and design of new molecules and materials such as drugs, catalysts, polymer, alloys, ceramics, and proteins. Students taking graduate version complete additional assignments. Students cannot receive credit without simultaneous completion of 6.C01.
R. Gomez-Bombarelli, C. Coley, E. Fraenkel

3.C27[J] Computational Imaging: Physics and Algorithms
Same subject as 2.C27[J], 6.C27[J]
Subject meets with 2.C67[J], 3.C67[J], 6.C67[J]
Prereq: 18.C06[J] and (1.00, 1.000, 2.086, 3.019, or 6.100A)
U (Fall)
3-0-9 units

See description under subject 2.C27[J].
G. Barbastathis, J. LeBeau, R. Ram, S. You

3.C51[J] Machine Learning for Molecular Engineering
Same subject as 10.C51[J], 20.C51[J]
Subject meets with 3.C01[J], 7.C01, 7.C51, 10.C01[J], 20.C01[J]
Prereq: Calculus II (GIR) and 6.100A; *Coreq: 6.C51*
G (Spring)
2-0-4 units
Credit cannot also be received for 1.C01, 1.C51, 2.C01, 2.C51, 3.C01[J], 7.C01, 7.C51, 10.C01[J], 20.C01[J], 22.C01, 22.C51, SCM.C51

Building on core material in 6.C51, provides an introduction to the use of machine learning to solve problems arising in the science and engineering of biology, chemistry, and materials. Equips students to design and implement machine learning approaches to challenges such as analysis of omics (genomics, transcriptomics, proteomics, etc.), microscopy, spectroscopy, or crystallography data and design of new molecules and materials such as drugs, catalysts, polymer, alloys, ceramics, and proteins. Students taking graduate version complete additional assignments. Students cannot receive credit without simultaneous completion of 6.C51.
R. Gomez-Bombarelli, C. Coley, E. Fraenkel

3.C67[J] Computational Imaging: Physics and Algorithms
Same subject as 2.C67[J], 6.C67[J]
Subject meets with 2.C27[J], 3.C27[J], 6.C27[J]
Prereq: 18.C06[J] and (1.00, 1.000, 2.086, 3.019, or 6.100A)
G (Fall)
3-0-9 units

See description under subject 2.C67[J].
G. Barbastathis, J. LeBeau, R. Ram, S. You

3.EPE UPOP Engineering Practice Experience
Engineering School-Wide Elective Subject.
Offered under: 1.EPE, 2.EPE, 3.EPE, 6.EPE, 8.EPE, 10.EPE, 15.EPE, 16.EPE, 20.EPE, 22.EPE
Prereq: None
U (Fall, Spring)
0-0-1 units
Can be repeated for credit.

See description under subject 2.EPE. Application required; consult UPOP website for more information.
K. Tan-Tiongco, D. Fordell

3.EPW UPOP Engineering Practice Workshop
Engineering School-Wide Elective Subject.
Offered under: 1.EPW, 2.EPW, 3.EPW, 6.EPW, 10.EPW, 16.EPW, 20.EPW, 22.EPW
Prereq: 2.EPE
U (Fall, IAP, Spring)
1-0-0 units

See description under subject 2.EPW. Enrollment limited to those in the UPOP program.
K. Tan-Tiongco, D. Fordell

3.S01 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
Staff

3.S02 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
Staff

3.S03 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
Staff

3.S04 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Spring)
Units arranged
Can be repeated for credit.

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
Staff

3.S05 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Spring)
Units arranged

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
Staff

3.S06 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Spring)
Units arranged
Can be repeated for credit.

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects.
Staff

3.S07 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Spring)
Units arranged
Can be repeated for credit.

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
Staff

3.S08 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Fall, Spring)
Units arranged [P/D/F]

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
Staff

3.S09 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Fall, IAP, Spring, Summer)
Not offered regularly; consult department
Units arranged [P/D/F]

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
Staff

3.S70 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
Units arranged

Covers advanced topics in Materials Science and Engineering that are not included in the permanent curriculum.
Staff

3.S71 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
Units arranged

Covers advanced topics in Materials Science and Engineering that are not included in the permanent curriculum.
Staff

3.S72 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
Units arranged

Covers advanced topics in Materials Science and Engineering that are not included in the permanent curriculum.
Staff

3.S74 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
G (Spring)
Units arranged

Covers advanced topics in Materials Science and Engineering that are not included in the permanent curriculum.
Staff

3.S75 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
G (Spring)
Units arranged

Covers advanced topics in Materials Science and Engineering that are not included in the permanent curriculum.
Staff

3.S76-3.S79 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
G (IAP)
Units arranged [P/D/F]

Covers advanced topics in Materials Science and Engineering that are not included in the permanent curriculum.
Staff

3.THG Graduate Thesis
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Program of research leading to the writing of an SM, PhD, or ScD thesis; to be arranged by the student and an appropriate MIT faculty member.
R. Macfarlane

3.THU Undergraduate Thesis
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Program of research leading to the writing of an SB thesis; to be arranged by the student and an appropriate MIT faculty member. Instruction and practice in oral and written communication.
Information: DMSE Academic Office

3.UAR[J] Climate and Sustainability Undergraduate Advanced Research
Same subject as 1.UAR[J], 5.UAR[J], 11.UAR[J], 12.UAR[J], 15.UAR[J], 22.UAR[J]
Prereq: Permission of instructor
U (Fall, Spring)
2-0-4 units
Can be repeated for credit.

See description under subject 1.UAR[J]. Application required; consult MCSC website for more information.
D. Plata, E. Olivetti

3.UR Undergraduate Research
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Extended participation in work of a research group. Independent study of literature, direct involvement in group's research (commensurate with student skills), and project work under an individual faculty member. See UROP coordinator for registration procedures.
Information: DMSE Academic Office

3.URG Undergraduate Research
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Extended participation in work of a research group. Independent study of literature, direct involvement in group's research (commensurate with student skills), and project work under an individual faculty member. See UROP coordinator for registration procedures.
Information: DMSE Academic Office