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 all types of 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 materials’ processing, structure, and properties) and applied science, i.e., engineering. Research projects in the Department of Materials Science and Engineering (DMSE) range from the purely scientific to practical applications. The department draws on scientific perspectives from chemistry, physics, and biology, while putting the analysis on firm mathematical footing. Applied research can incorporate elements of 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 and must also have a proper concern for 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.

Fundamental concepts cited above are taught in core subjects and electives in these areas 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 by selecting subjects that focus on archaeological materials research within the Department of Materials Science and Engineering and the Center for Materials Research in Archaeology and Ethnology (CMRAE). This curriculum is unique within departments of anthropology, archaeology, and engineering.

Materials engineers and materials scientists, whether generalists or specialists in a particular class of material, are in continually high demand by industry and government for jobs in research, development, production, and management. They find a diversity of challenging opportunities in important positions at companies working on energy and the environment, in the electronics industry, in the aerospace industry, in consumer products industries, and in biomaterials and medical industries. A large number of DMSE alumni are faculty at leading universities.

The department has modern 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 Laboratory for Advanced Materials contains characterization equipment for scanning acoustical microscopy, near-field and scanning laser confocal microscopes, and a low-temperature multiprobe. Other departmental facilities include those for preparation and characterization of thin films, ceramics and glasses, metallic and nonmetallic crystals, biomaterials, and polymers. Materials are characterized by optical, electron (TEM, SEM), and scanning probe (AFM, STM) microscopy, and there is equipment for a wide range of electrical, optical, magnetic, and mechanical property measurements. DMSE faculty, students, and staff will be among the key users of the new MIT.nano (https://mitnano.mit.edu) building, a state-of-the-art facility for materials research that opened October 2018.

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 ABET (http://www.abet.org).
- **Course 3-A**, leading to the Bachelor of Science without specification, provides students greater flexibility in designing their own self-guided program. The New Engineering Education Transformation (NEET) program (https://neet.mit.edu/threads/advanced-materials-machines) offers a thread in Advanced Materials Machines that meets the 3-A requirements.
- **Course 3-C** leads to a Bachelor of Science in Archaeology and Materials.

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 (http://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 may substitute industrial internship reports (12 units of Industrial Practice, 3.930/3.931 Internship Program) for the senior thesis (3.THU Undergraduate Thesis). Students select this option during their sophomore year, and take 3.930 in the summer after the sophomore year and 3.931 in the summer following the junior year. This option provides students with industrial experience concurrently with academic work through cooperative work assignments matched to each student’s capabilities and arranged by the department. A company representative and a faculty advisor act as co-supervisors during the students’ assignments. Students earn a salary during their work periods and also receive academic credit.

Bachelor of Science (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 more biology and chemistry subjects in preparation for medical school or more management subjects prior to entering an MBA or law program. 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 (http://catalog.mit.edu/degree-charts/materials-science-engineering-course-3-a) for Course 3-A are similar to but more flexible than those for Course 3.

A student considering the 3-A program (including NEET) 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.

The NEET option allows students to pursue a project-centered academic program across multiple departments and disciplines.

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 (http://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 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** The Human Past: Introduction to Archaeology
- **3.985[J]** Archaeological Science

Select two other HASS electives from among the following:

- **3.094** 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 Archaeology and Materials

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

#### Required Subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.012</td>
<td>Fundamentals of Materials Science and Engineering</td>
<td>15</td>
</tr>
<tr>
<td>3.014</td>
<td>Materials Laboratory</td>
<td>12</td>
</tr>
<tr>
<td>3.022</td>
<td>Microstructural Evolution in Materials</td>
<td>12</td>
</tr>
<tr>
<td>3.985[J]</td>
<td>Archaeological Science (HASS-S)</td>
<td>9</td>
</tr>
<tr>
<td>3.986</td>
<td>The Human Past: Introduction to Archaeology (HASS-S)</td>
<td>12</td>
</tr>
</tbody>
</table>

#### Elective

Select one of the following: 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: 69-72**

*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. Max Price, will ensure that the minor program forms a coherent group of subjects.

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

### Inquiries

Additional information regarding undergraduate programs may be obtained from the DMSE Academic Office, Room 6-107, 617-258-5816.

### 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.

### Admission Requirements for Graduate Study

General admissions requirements are described under Graduate Education (http://catalog.mit.edu/mit/graduate-education/general-
degree-requirements). 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 3.012 Fundamentals of Materials Science and Engineering and 3.022 Microstructural Evolution in Materials.

Requirements for Completion of Graduate Degrees
The general 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 are described under the section on Graduate Education (http://catalog.mit.edu/mit/graduate-education/general-degree-requirements). 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 are described under Graduate Education (http://catalog.mit.edu/mit/graduate-education/general-degree-requirements). 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 are found in the section detailing degree requirements under Graduate Education (http://catalog.mit.edu/mit/graduate-education/general-degree-requirements). 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
All doctoral degree programs have the same foundation of required subjects:

<table>
<thead>
<tr>
<th>Doctoral Program Core Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.20</td>
</tr>
<tr>
<td>3.21</td>
</tr>
<tr>
<td>3.22</td>
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<td>3.23</td>
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</tbody>
</table>

The general written examination covers material in the doctoral core.

In the thesis area examination (oral presentation and examination), students are expected to learn the fundamentals of their chosen field and to develop a deep understanding of one or more of its significant aspects. Students are required to take three further subjects from an approved restricted electives list. 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. The thesis area examinations for the doctoral degree are designed accordingly. In addition, students are required to take a two- or three-subject minor program.

Research is considered the central part of the educational process at the graduate level. Students choose research projects from the many opportunities that exist within the department, and work closely under the supervision of an individual faculty member. 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.

The department maintains a large number of well-equipped research laboratories, and there is significant interaction between them, including the sharing of experimental facilities and equipment. Most department members have access to the Materials Research Laboratory, which provides and maintains excellent central facilities and interdisciplinary research opportunities as described in the section on Research and Study (http://catalog.mit.edu/mit/research).

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.

**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 under Interdisciplinary Graduate Programs (http://catalog.mit.edu/interdisciplinary/graduate-programs/polymers-soft-matter).

**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 or 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 (http://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**
Additional information regarding graduate programs, admissions, and financial aid may be obtained by contacting the Academic Office (dmse-admissions@mit.edu), Room 6-107.

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Professor Emeritus of Nuclear Science and Engineering

Subra Suresh, ScD  
Vannevar Bush Professor Emeritus of Engineering

Edwin L. Thomas, PhD  
Professor Emeritus of Materials Science
3.001 Introduction to Materials Science and Engineering
Prereq: None
U (Spring)
2-0-1 units
Provides a broad introduction to topics in materials science and the curricula in the Department of Materials Science and Engineering's core subjects. Lectures emphasize conceptual and visual examples of materials phenomena and engineering, interspersed with guest speakers from both inside and outside academia to show possible career paths. Subject can count toward the 9-unit discovery-focused credit limit for first-year students. Preference to first-year students.

F. M. Ross

3.003 Principles of Engineering Practice
Subject meets with 3.004
Prereq: Calculus I (GIR) and Physics I (GIR)
U (Spring)
1-2-6 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 participation in engineering projects. 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. Preference to first-year students.

L. Kimerling

3.004 Principles of Engineering Practice
Subject meets with 3.003
Prereq: Calculus I (GIR) and Physics I (GIR)
U (Spring)
3-3-6 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 participation in engineering projects. 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. Preference to first-year students; limited to 15.

L. Kimerling

3.005 Passion Projects: Living in a Material World
Prereq: None
U (Spring)
Not offered regularly; consult department
1-2-6 units
Project-based seminar in which students formulate and answer questions about a material or object that interests and inspires them. Uses cutting-edge equipment to characterize the materials' structure in order to understand its role and functionality. Analyzes the lifecycle of the material to better understand the full use case. Culminates in the creation of a website, video, and final presentation in which students share the results of their research. Preference to first-year students; limited to 15.

J. Grossman

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
3.007 Introduction to Materials and Mechanical Design
Prereq: None
U (Fall)
2-3-1 units
Focuses on hands-on experience with characterization techniques, instrumentation, design thinking and optimizing solutions within design constraints. Applied to ideas relevant to materials science and mechanical engineering. Includes introductions to modern, rapid prototyping and characterization tools in the context of a design problem, followed by discovery-based labs illustrating manufacturing concepts. Culminates in a student-directed making experience.
E. Olivetti

3.012 Fundamentals of Materials Science and Engineering
Prereq: Chemistry (GIR) and Coreq: (3.016A, 18.03, or 18.032); or permission of instructor
U (Fall)
5-0-10 units. REST
Describes the fundamentals of structure and energetics that underpin materials science. Presents thermodynamic concepts and the laws governing equilibrium properties, and the connections between thermodynamic concepts and materials phenomena, such as phase transformations, multiphase equilibria, and chemical reactions. Introduces computerized thermodynamics. Structure of noncrystalline, crystalline, and liquid-crystalline states. Symmetry and tensor properties of materials. Point, line, and surface imperfections in materials. Diffraction and structure determination.
R. Jaramillo, C. Ross

3.014 Materials Laboratory
Prereq: None
U (Fall)
1-4-7 units. Institute LAB
Experimental exploration of the connections between structure, properties, processing, and performance of materials. Hands-on experience with materials characterization techniques and instrumentation. Covers methodology of technical communication (written and oral) with a view to integrate experimental design, execution, and analysis. Concurrent enrollment in 3.012 and 3.014 strongly recommended.
J. LeBeau, D. Sadoway

3.016A Computational and Mathematics Preparation for Materials Scientists and Engineers I (New)
Prereq: Calculus II (GIR); Coreq: 3.012
U (Fall)
3-0-3 units
Introduces 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). Students 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 3.012 and 3.014.
W. C. Carter

3.016B Computational and Mathematics Preparation for Materials Scientists and Engineers II (New)
Prereq: 3.016A; Coreq: 3.022 and 3.024
U (Spring)
3-0-3 units
Continues 3.016A with applications to microstructural evolution, electronic optical and magnetic properties of materials. Topics in 3.022 and 3.024 are emphasized and reinforced with visualization, computational, and mathematical techniques. Mathematics topics include symbolic and numerical solutions to partial differential equations, Fourier analysis, Bloch waves, analysis of random walks, linear stability analysis.
W. C. Carter

3.017 Modelling, Problem Solving, Computing, and Visualization
Prereq: ((3.014, 3.022, or 3.024) and (3.016B, 6.0001, 12.010, or 16.66)) or permission of instructor
U (Spring)
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
3.021 Introduction to Modeling and Simulation
Engineering School-Wide Elective Subject.
Offered under: 1.021, 3.021, 10.333, 22.00
Prereq: 3.016B, 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, R. Gomez-Bombarelli

3.022 Microstructural Evolution in Materials
Prereq: 3.012
U (Spring)
3-3-6 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.

J. Hu, G. Beach, Y. Chiang

3.024 Electronic, Optical and Magnetic Properties of Materials
Prereq: 3.012
U (Spring)
3-3-6 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.

P. Anikeeva, G. Beach, Y. Chiang

3.032 Mechanical Behavior of Materials
Prereq: Physics I (GIR) and (3.016B or 18.03)
U (Fall)
3-1-8 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 and demonstrations give hands-on experience of the physical concepts. Offers a combination of online and in-person instruction.

C. Tasan, M. Dao

3.034 Organic and Biomaterials Chemistry
Subject meets with 3.034A
Prereq: 3.012
U (Fall)
4-2-6 units

Focuses on the chemistry and chemical structure-property relationships of soft synthetic and biologically derived materials, and aims to develop a fundamental understanding of the molecular nature of materials. Topics include methods for preparing synthetic polymers by step- and chain-growth polymerizations; polymerization reaction kinetics; chemistry of proteins and nucleic acids; DNA nanotechnology; synthetic polypeptides and artificial amino acids; application of biologically derived materials into biomedical and sensing applications; electroactive organic materials; and polymer processing and mechanical properties. Includes firsthand application of lecture topics through design-oriented experiments.

R. Macfarlane

3.034A Organic and Biomaterials Chemistry
Subject meets with 3.034
Prereq: Chemistry (GIR)
U (Fall)
4-0-8 units

Focuses on the chemistry and chemical structure-property relationships of soft synthetic and biologically derived materials. Topics include methods for preparing synthetic polymers by step and chain growth polymerizations; polymerization reaction kinetics; chemistry of proteins, nucleic acids, polysaccharides and lipids; enzymatic reactions; electroactive organic materials; polymer mechanical properties and processing techniques; applications of biological and biomaterials; self-assembly of polymer, nanoparticle, and biological materials; instrumental techniques for characterizing soft materials. 3.034A students also complete additional written assignments in place of the 3.034 laboratory component.

R. Macfarlane
3.035 Problems in Materials Science and Engineering
Prereq: Permission of instructor
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

For undergraduates desiring to carry on projects of their own choosing, which may be experimental, theoretical, or of a design nature. Also for undergraduate studies arranged by students or staff, which may consist of seminars, assigned reading, or laboratory projects. See UROP Coordinator for registration procedures.

3.038 Problems in Materials Science and Engineering
Prereq: Permission of instructor
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.

For undergraduates desiring to carry on projects of their own choosing, which may be experimental, theoretical, or of a design nature. Also for undergraduate studies arranged by students or staff, which may consist of seminars, assigned reading, or laboratory projects. See UROP Coordinator for registration procedures.

3.042 Materials Project Laboratory
Prereq: 3.014, 3.032, or 3.044
U (Fall, Spring)
1-6-5 units

Student project teams design and fabricate a working prototype using materials processing technologies (e.g. solid works 3-D design software, computer numerical controlled mill, injection molding, thermoforming, investment casting, powder processing, three-dimensional printing, physical vapor deposition) appropriate for the materials and device of interest. Goals include using MSE fundamentals in a practical application; understanding trade-offs between design, processing, and performance and cost; and fabrication of a deliverable prototype. Emphasis on teamwork, project management, communications and computer skills, with extensive hands-on work using student and MIT laboratory shops. Teams document their progress and final results by means of written and oral communication. Limited to 25.

M. Tarkanian

3.044 Materials Processing
Prereq: 3.012 and 3.022
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 Thermodynamics of Materials
Prereq: 3.012 or permission of instructor
U (Spring)
3-0-9 units. REST

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: 3.032 or permission of instructor
Acad Year 2019-2020: U (Spring)
Acad Year 2020-2021: 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], 6.024[J], 20.310[J]
Prereq: Biology (GIR), (2.370 or 20.110[J]), and (3.016B or 18.03)
U (Spring)
4.0-8 units
See description under subject 20.310[J].
M. Bathe, A. Grodzinsky

3.054 Cellular Solids: Structure, Properties, Applications
Subject meets with 3.36
Prereq: 3.032
U (Spring)
2.0-10 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: 3.034, 20.110[J], or permission of instructor
U (Fall)
3.0-9 units
See description under subject 20.363[J].
D. Irvine, K. Ribbeck

3.063 Polymer Physics
Subject meets with 3.942
Prereq: 3.012
U (Spring)
4.0-8 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

3.064 Polymer Engineering
Prereq: 3.032 and 3.044
U (Fall)
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.
N. Holten-Andersen

3.07 Introduction to Ceramics
Prereq: 3.012
U (Fall)
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: (3.022 and 3.024) or permission of instructor
U (Fall)
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: 3.024
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: 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, F. Ross

3.080 Strategic Materials Selection
Prereq: 3.012, 3.014, or permission of instructor
U (Spring)
3-0-9 units
Provides a survey of methods for evaluating choice of material and explores the implications of that choice. Topics include manufacturing economics and utility analysis. Students carry out a group project selecting materials technology options based on economic characteristics.
R. Kirchain

3.081 Industrial Ecology of Materials
Subject meets with 3.560
Prereq: 3.012, 3.014, or permission of instructor
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, 3.012, 10.467, or permission of instructor
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: 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

3.091 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).

J. Grossman, N. Holten-Andersen, R. Macfarlane

3.094 Materials in Human Experience
Prereq: None
U (Spring)
2-3-4 units. HASS-S

Examines the ways in which people in ancient and contemporary societies have selected, evaluated, and used materials of nature, transforming them to objects of material culture. Some examples: Maya use of lime plaster for frescoes, books and architectural sculpture; sounds and colors of powerful metals in Mesoamerica; cloth and fiber technologies in the Inca empire. Explores ideological and aesthetic criteria often influential in materials development. Laboratory/workshop sessions provide hands-on experience with materials discussed in class. Subject complements 3.091. Enrollment may be limited.

H. N. Lechtman, D. Hosler

3.095 Introduction to Metalsmithing
Prereq: None
U (Spring)
2-3-4 units. HASS-A

Centers around art history, design principles, sculptural concepts, and metallurgical processes. Covers metalsmithing techniques of enameling, casting, and hollowware. Students create artworks that interpret lecture material and utilize metalsmithing techniques and metal as means of expression. Also covers topics of art patronage, colonial influence upon arts production, and gender and class issues in making. Lectures and lab sessions supplemented by a visiting artist lecture and art museum field trip. Limited to 12.

T. Fadenrecht

3.14 Physical Metallurgy
Subject meets with 3.40[J], 22.71[J]
Prereq: 3.022 and 3.032
U (Fall)
Not offered regularly; consult department
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, particularly steels and aluminum alloys. Students taking the graduate version explore the subject in greater depth.

C. Tasan

3.15 Electrical, Optical, and Magnetic Materials and Devices
Prereq: 3.024
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: 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.

J. L.M. Rupp
3.152 Magnetic Materials
Subject meets with 3.45
Prereq: 3.024
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: 3.032 and 3.044
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (Spring)
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

Same subject as 6.152[J]
Prereq: Calculus II (GIR), Chemistry (GIR), Physics II (GIR), or permission of instructor
U (Fall)
3-4-5 units
See description under subject 6.152[J]. Enrollment limited. J. Michel, J. Scholvin

3.156 Photonic Materials and Devices
Subject meets with 3.46
Prereq: 3.024 and (3.016B or 18.03)
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (Fall)
3-0-9 units

3.16 Industrial Challenges in Metallic Materials Selection
Subject meets with 3.39
Prereq: 3.012 or permission of instructor
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: 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. T. Carneiro
3.171 Structural Materials and Manufacturing
Prereq: 3.012 and 3.014
U (Fall, Spring; partial term)
2-0-10 units
Can be repeated for credit. Credit cannot also be received for 2.821[J], 3.371[J]
Combines online and in-person lectures to discuss structural materials selection, design and processing using examples from deformation processes, casting, welding and joining, non-destructive evaluation, failure and structural life assessment, and codes and standards. Emphasizes the underlying science of a given process rather than a detailed description of the technique or equipment. Presented in modules to be selected by student. Students taking graduate version must submit additional work. Meets with 3.371[J] when offered concurrently.
T. Eagar

3.18 Materials Science and Engineering of Clean Energy
Subject meets with 3.70
Prereq: 3.022 and 3.024
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.
D. Sadoway

3.19 Sustainable Chemical Metallurgy
Subject meets with 3.50
Prereq: 3.022
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: 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: (3.012, 3.014, 3.022, 3.024, 3.034, and 3.042) or permission of instructor
G (Fall)
5-0-10 units
A. Allanore

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: 3.012, 3.022, 3.044, 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 Mechanical Behavior of Materials
Prereq: 3.032 or permission of instructor
G (Spring)
4-0-8 units
Explores how the macroscale mechanical behavior of materials originates from fundamental, microscale mechanisms of elastic and inelastic deformation. Topics include: elasticity, viscoelasticity, plasticity, creep, fracture, and fatigue. Case studies and examples are drawn from a variety of material classes: metals, ceramics, polymers, thin films, composites, and cellular materials.
C. Tasan

3.23 Electrical, Optical, and Magnetic Properties of Materials
Prereq: 8.03 and 18.03
G (Fall)
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. 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

3.24 Structure of Materials (New)
Prereq: Permission of instructor
G (Fall)
3-0-9 units
Studies the underlying structure of materials in order to deepen understanding of structure-property relationships. For crystalline materials, fundamentals of structural description includes lattices, point and space groups, symmetry and tensor properties. Concepts of structure will then be discussed for other types of material: soft matter, amorphous solids, liquid crystals, two-dimensional materials and nanostructured materials. Includes structural descriptions of interfaces and defects. Also introduces some of the key techniques for structure determination.
F. M. Ross, J. LeBeau, S. Gradecak

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
G (Fall)
3-0-9 units
See description under subject 22.74[J].
M. Short, B. Yildiz

3.320 Atomistic Computer Modeling of Materials
Prereq: 3.022, 3.20, 3.23, or permission of instructor
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Fall)
3-0-9 units
Staff

3.33[J] Defects in Materials
Same subject as 22.73[J]
Prereq: 3.21 and 3.22
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: 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: 3.024, 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, computer simulations/data analysis, and a parallel hands-on laboratory.
J. LeBeau, F. M. Ross, S. Gradecak

3.35 Fracture and Fatigue
Prereq: 3.22 or permission of instructor
Acad Year 2019-2020: G (Spring)
Acad Year 2020-2021: 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: 3.032 or permission of instructor
G (Spring)
2-0-10 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.
Staff

3.371[J] Structural Materials
Same subject as 2.821[J]
Prereq: Permission of instructor
G (Fall, Spring, Summer; partial term)
2-0-10 units
Can be repeated for credit. Credit cannot also be received for 3.171

Combines online and in-person lectures to discuss structural materials selection, design and processing using examples from deformation processes, casting, welding and joining, non-destructive evaluation, failure and structural life assessment, and codes and standards. Emphasizes the underlying science of a given process rather than a detailed description of the technique or equipment. Presented in modules to be selected by student. Students taking graduate version must submit additional work. Meets with 3.171 when offered concurrently.
T. Eagar, A. Slocum
3.38 Ceramics: Processing, Properties and Functional Devices
Prereq: None
G (Fall)
3-0-9 units

Explores modern ceramic processing - ranging from large-scale synthesis, 3D manufacturing and printing to nanoscale-thin film structures integrated for microelectronics useful for material, chemical, electronic or mechanical engineers. Examples of devices studied include opto-electronic materials, sensors, memories, batteries, solar-to-fuel convertors, and solid oxide fuel cells. Provides the skills and guidance to design ceramic and glassy materials for large-scale components as energy storage or convertors, or for nano-scale electronic applications in information storage devices.

J. L. M. Rupp

3.39 Industrial Challenges in Metallic Materials Selection
Subject meets with 3.16
Prereq: 3.20 or permission of instructor
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: 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 structural 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.

T. Carneiro

3.40[J] Modern Physical Metallurgy
Same subject as 22.71[J]
Subject meets with 3.14
Prereq: 3.022 and 3.032
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Fall)
3-0-9 units

Examines how the presence of 1-, 2- and 3-D defects and second phases control the mechanical, electromagnetic and chemical behavior of metals and alloys. Considers point, line and interfacial defects in the context of structural transformations including annealing, spinodal decomposition, nucleation, growth, and particle coarsening. Concentrates on structure-function relationships, and in particular how grain size, interstitial and substitutional solid solutions, and second-phase particles impact mechanical and other properties. Industrially relevant case studies illustrate lecture concepts. Students taking the graduate version explore the subject in greater depth.

C. Tasan

3.41 Colloids, Surfaces, Absorption, Capillarity, and Wetting Phenomena
Prereq: 3.20 and 3.21
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: 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 (Fall)
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 Integrated Microelectronic Devices
Same subject as 6.720
Prereq: 3.42 or 6.012
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Fall)
4-0-8 units
See description under subject 6.720.
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, magnetooptical 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
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Fall)
3-0-9 units
J. Hu
3.50 Sustainable Chemical Metallurgy
Subject meets with 3.19
Prereq: 3.022 or permission of instructor
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: 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)
3-0-6 units

D. R. Sadoway

3.560 Industrial Ecology of Materials
Subject meets with 3.081
Prereq: 3.20 or permission of instructor
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
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Spring)
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

3.65 Soft Matter Characterization
Prereq: Permission of instructor
G (Fall)
1-2-9 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 lab 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.

J. Ortony

3.69 Teaching Fellows Seminar
Prereq: None
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.

C. Schuh
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.

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.

3.694 Teaching Materials Science and Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

undefined

D. Sadoway

3.693-3.699 Teaching Materials Science and Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
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.

D. Sadoway

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 (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.

T. Eagar

3.931 Internship Program
Prereq: 3.930
U (Fall, 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.

T. Eagar
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
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
Prereq: 3.032 or permission of instructor
G (Spring)
4-0-8 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

3.963[J] Biomaterials Science and Engineering
Same subject as 20.463[J]
Subject meets with 3.055[J], 20.363[J]
Prereq: 3.034, 20.110[J], or permission of instructor
Acad Year 2019-2020: G (Fall)
Acad Year 2020-2021: Not offered
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], 6.524[J], 10.537[J], 20.410[J]
Prereq: Biology (GIR) and (2.002, 2.006, 6.013, 10.301, or 10.302)
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Fall)
3-0-9 units
See description under subject 20.410[J].
R. D. Kamm, K. J. Van Vliet

Archaeology and Archaeological Science

3.981 Communities of the Living and the Dead: the Archaeology of Ancient Egypt
Prereq: None
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (Spring)
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 (Spring)
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.
D. Hosler
3.983 Ancient Mesoamerican Civilization
Prereq: None
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: Ceramics
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 ceramic materials, including clays and mortars. Seminars cover basic ceramic materials science and engineering and relate materials selection and processing to environment, exchange, political power, and cultural values.
H. N. Lechtman, J. Meanwell

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.
H. N. Lechtman

3.986 The Human Past: Introduction to Archaeology
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.
M. Price

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.
M. Price

3.989 Materials in Ancient Societies: Ceramics Laboratory
Prereq: Permission of instructor
G (Spring)
3-6-3 units
Laboratory analysis of archaeological artifacts of ceramics. Follows on 3.984.
J. Meanwell

3.990 Seminar in Archaeological Method and Theory
Prereq: 3.985[J], 3.986, and 21A.00
U (Fall, 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.
D. Hosler, H. Lechtman
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.
M. Price

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.
D. Hosler, H. Lechtman

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.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: 2.EPW or permission of instructor
U (Fall, Spring)
0-0-1 units
See description under subject 2.EPE.
Staff

3.501 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Fall)
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

3.502 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Fall)
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

3.503 Special Subject in Materials Science and Engineering
Prereq: Permission of instructor
U (Fall)
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

3.504 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 (Fall, 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.S07 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]  
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, 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.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.S72 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.S70-3.S75 Special Subject in Materials Science and Engineering  
Prereq: Permission of instructor  
G (Fall)  
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 (Fall)  
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.  
D. Sadoway

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.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