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The School of Architecture and Planning—like all great academic institutions—is an extraordinarily complex, diverse, sometimes contentious, always evolving and transforming place. There are, however, some widely shared beliefs and values that give the School its unique character and direction. We are committed to sustaining and enhancing the quality of the human environment at all scales, from the personal to the global. We value design excellence, technological inventiveness, and imaginative scholarship. And we believe that design and policy interventions should be grounded in unwavering commitment to equity, social justice, and making a positive difference in the everyday lives of real people.
The School of Architecture and Planning is made up of five main divisions—the Department of Architecture, the Department of Urban Studies and Planning, the Media Laboratory, the Center for Real Estate, and the Center for Advanced Visual Studies.

The unifying theme of all our activities is design. Through the design of physical spaces, and through the design of policies and technologies that shape how those spaces are used, we aim to sustain and enhance the quality of the human environment at all scales, from the personal to the global.

We believe that design and policy interventions should be grounded in a commitment to improving individual human lives, equity and social justice, cultural enrichment, and the responsible use of resources through creative problem solving and project execution.

Students

The School of Architecture and Planning enrolls an average of 600 students a year in an array of courses ranging from Renaissance architecture to the cities of tomorrow, digital fabrication, motion graphics, shape grammars, photography, and construction finance. By far the largest number of those students enter our graduate programs and many of them also pursue cross-disciplinary studies and dual degrees among those programs and others at the Institute.

Throughout the years, we have been noted for the diversity of our student body, drawing on candidates from around the world and from all walks of life. The Department of Architecture graduated its first woman, Sophia Hayden, in 1890, and three years later, Robert Taylor became the first African-American to graduate from an American architecture program—a tradition of inclusiveness that continues today. In academic year 2005–2006, roughly 45% of our students were women, 18% were minorities, and 32% came from other countries.

Collaboration

An important aspect of the School’s teaching and research activities is our ongoing participation in collaborative undertakings—among our five divisions, with other divisions of MIT, and with public and private institutions in the US and abroad. In addition to more than 100 ongoing efforts, we are currently launching two new programs to strengthen further the links among ourselves and to the world at large.

The Design Laboratory will be organized as a collection of multidisciplinary teams that blur the boundaries of the specialization areas in our School. A central goal of the lab is to provide opportunities, infrastructure, and a peer community for faculty, staff, and students who are interested in pursuing innovative design research.

The Urbanization Laboratory will build on our 20-year relationship with Tsinghua University in Beijing to focus on the design and development issues posed by rapid urbanization in China and elsewhere. The goal is to invent new models of city form and function that will accommodate such fast growth without sacrificing livability.

History

Our history stretches back nearly a century and a half, providing our current students with a legacy and long tradition of pioneering excellence. The Department of Architecture was the first such department in the nation (1865) and became a leader in introducing Modernism to America. The program in city planning was the second of its kind in the country (1932), later evolving into the current Department of Urban Studies and Planning, the longest continuous planning program in the United States.

The Media Lab, the birthplace of multimedia computing (1985), has come to be known around the world as a world-class incubator of new design ideas; the Center for Real Estate established the nation’s first one-year graduate program in real estate development (1984); and the Center for Advanced Visual Studies (1967), now a thriving fellowship program, pioneered the use of technologies such as lasers, plasma sculptures, sky art, and holography as tools of expression in public and environmental art.

Resources

The Rotch Library is one of the nation’s premier resources in architecture and planning; Rotch Visual Collections, an adjacent branch library, holds 350,000 visual images, including the Aga Khan Visual Archive.

The School’s Wolk Gallery mounts several shows a year in its exhibition space, overseen by the curator of architecture and design at the MIT Museum. The PLAZmA Digital Gallery is an electronic showcase of work and events on display in the School’s public areas, featuring faculty and student work.

The School’s newsletter, PLAN, is published in print and online by the Dean’s Office, Room 7-231. The five divisions of the School can be contacted directly about their array of publications.

Office of the Dean

Adèle Naudé Santos, AADipl, MArchUD, MArch, MCP
Professor of Architecture and Urban Planning
Dean
Diane Davis, BA, MA, PhD
Professor of Political Sociology
Associate Dean
Diane McLaughlin, MBA
Assistant Dean for Administration
Tia Tilson
Assistant Dean for Resource Development
Scott Campbell
Director of Communications
James Harrington, MS, MArch
Facilities Manager
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<th>Course</th>
<th>Notes</th>
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<td>Architecture: History and Theory of Architecture</td>
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<tr>
<td>PhD</td>
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<td>Architecture: History and Theory of Art</td>
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**Media Arts and Sciences - Course MAS**

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<td>SM</td>
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<td>Media Arts and Sciences</td>
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**Urban Studies and Planning - Course 11**

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<td>Simultaneous degree in City Planning and Real Estate Development</td>
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<td>Urban Design Certificate</td>
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<tr>
<td>PhD</td>
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<td>Urban and Regional Studies</td>
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**Center for Real Estate**

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<tr>
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<tr>
<td>SMRED</td>
<td></td>
<td>Real Estate Development</td>
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**Notes:** Many departments make it possible for a graduate student to pursue a simultaneous master’s degree. Several departments also offer undesignated degrees, which lead to the Bachelor of Science without departmental designation. The curricula for these programs offer students opportunities to pursue broader programs of study than can be accommodated within a four-year departmental program.
The Department of Architecture conceives of architecture as a discipline as well as a profession. Five semi-autonomous, graduate degree-granting “discipline groups” provide an architectural education that is as complex as the field itself. Each discipline group is supported by the other four, and all five contribute to a mutual enterprise. Students learn ways of working that draw upon the whole range of resources that architecture affords in finding and defining the expansive problems of building, as well as in proposing effective solutions. The groups are Architectural Design; Building Technology; Computation; History, Theory and Criticism of Architecture and Art (HTC); and Visual Arts.

In the several disciplines of the department, there is a substantial body of research activity. Moreover, the department’s setting within MIT permits greater depth in such technical areas as computation, new modes of design and production, materials, structure, and energy as well as in the arts, humanities and area studies. The department builds on, and contributes to, such valuable institutional commitments.

The department offers six degree programs: the Bachelor of Science in Art and Design, Master of Architecture, Master of Science in Architecture Studies, Master of Science in Building Technology, Master of Science in Visual Studies, and the Doctor of Philosophy.

In the United States, most state registration boards require a degree from an accredited professional degree program as a prerequisite for licensure. The National Architectural Accrediting Board (NAAB), which is the sole agency authorized to accredit US professional degree programs in architecture, recognizes three types of degrees—the Bachelor of Architecture, Master of Architecture, and Doctor of Architecture. A program may be granted a six-year, three-year, or two-year term of accreditation, depending on the extent of its conformance with established educational standards.

Master’s degree programs may consist of a preprofessional undergraduate degree and a professional graduate degree, which, when earned sequentially, constitute an accredited professional education. However, the preprofessional degree is not, by itself, recognized as an accredited degree.

The Department of Architecture offers the MArch degree in programs ranging from two to three and one-half years. These professional degrees are structured to educate those who aspire to registration and licensure as architects.

The undergraduate Bachelor of Science in Art and Design is a preprofessional degree program. It is useful for those wishing a foundation in the field of architecture as preparation for either continued education in a professional degree program or for employment options in architecturally related fields.

Architectural Design is taught from a broad range of perspectives linking several common concerns: site and context, use and form, building methods and materials, and the role of the architect. Context is considered in terms of existing and historical physical form (natural and constructed) and sociological patterns of use. The architect is seen less as the sole creator of a completed building than as a participant with others in the shaping of our physical environment.

Diverse architectural design studios are offered. After establishing a basis in a core curriculum, the focus shifts to choices among design projects of ascending complexity. Introductory studios provide a basic architectural design background and help undergraduates decide whether they want to continue in architecture. Entering graduate students have a basic studio crafted for their needs. The intermediate studios provide a range of experiences of form-making in which individual faculty present their particular ways of exploring a design issue. The advanced studios give graduate students the opportunity to sharpen their skills and to develop their own attitudes of form-making. In their theses, students carry through a project of their own from concept through theory and design to a final product.

Computer resources for educational purposes are distributed in the laboratories and studios of the department and overseen by the staff of the Computer Resource Office. Students are required to learn the fundamentals of computer-aided visualization. Other computation subjects or studio work permit further experimentation with modeling techniques, graphic representations, design methods, technical analysis, prototyping, and assistance with the design process. Students may also participate in research work in these areas.

The work of the Architectural Design faculty extends beyond the studio. Workshops, lectures, seminars, and research engage the built environment, the forces that mold it, and the design process itself. The work of the faculty covers such areas as large-scale physical settings, environmental programming, the form and evaluation of cities, computation and architecture, architectural theory and design methodology, decision-making procedures in design, housing and settlement forms in developing countries, self-help processes, and design in nonwestern cultures. Central to these topics is the role of the user as an active force in the development of environments and the role of the designer as an agent in the process of human habitation.

This group offers a concentration to undergraduates in Course 4 as well as Master of Architecture and Master of Science in Architecture Studies degrees.

Building Technology includes teaching and applications of the fundamentals of technology as well as research in technology for the next generation of buildings. Topics include building structures, materials, industrialized building systems, appropriate technology for developing countries, sustainable design, new indoor air quality technologies, and development of computational methods for research and design through visualization of building performance in its many aspects. Subjects include fundamentals of technology, applications to buildings, laboratories, and independent research projects. For example, students may study problems of energy resources and technologies and use this knowledge to design physical environments or buildings for the next decade that embody current research concepts. Research facilities include the Building Technology Laboratory, a full-scale indoor environmental chamber, as well as computer work stations. Research facilities of other departments such as Mechanical and Civil and Environmental Engineering are also used in joint research projects.

This group offers a concentration to undergraduates in Course 4 as well as a Master of Science in Building Technology (SMBT) and a doctoral degree with emphasis on building technology.

The Computation group teaches diverse subjects dealing with theory, history, methods, and applications of computation and digital
technology. The aim is to cover the many facets of a rapidly changing and growing area with in-depth, agenda-setting research and teaching. Topics taught cover the description, generation, and construction of architectural and urban form and other designed artifacts using computational means, including computer visualization, rendering, and modeling; generative theories, strategies, and software for design synthesis and analysis; and digital fabrication and construction processes and technologies. Students are encouraged to acquire both the technical skills and the theoretical and conceptual foundations to rethink and challenge the limits of current design processes and practices, and to consider the social and cultural implications of their positions.

The Computation group offers subjects at the graduate and undergraduate levels. It is responsible for a concentration in the Master of Science in Architecture Studies (SMArchS) program, and for a doctoral program. SMArchS and PhD students are encouraged to take subjects in other discipline areas as a means to explore and develop their interests.

The History, Theory, and Criticism of Architecture and Art group teaches subjects dealing with the history of art and architecture. Offerings range in content and method. Some study questions internal to the discipline of architecture, while others seek contexts in social, political, and intellectual history. Some are motivated by questions derived from the problems of contemporary practice. Others take their organization from a body of historical material investigated in ways that develop skills of analysis applicable to a wide range of topics. The group teaches subjects from the Renaissance forward in time, focusing on materials that are both abstract and concrete, with scales that range from the architectural drawing to the urban environment. There is a special emphasis on topics of modern art and architecture.

The Visual Arts group offers a diverse range of subjects in studio practice. Emphasis is placed on the development of the student’s ideas in relation to experimental media. Discussion in contemporary art and theory complements studio production.

This group offers a concentration to undergraduates in Course 4 and a HASS concentration in the visual arts to all undergraduates. It also offers a graduate major leading to a Master of Science in Visual Studies. Undergraduate and graduate subjects are also offered to students from other disciplines who would like to experiment in the visual arts.

More information about the Department of Architecture and its programs can be found on the department’s home page. The URL is http://architecture.mit.edu/.

UNDERGRADUATE STUDY

The Department of Architecture offers two undergraduate courses of study. They provide a broad undergraduate education for students who have clear professional goals and for those who desire a solid foundation for a number of possible careers. Course 4 leads to the Bachelor of Science in Art and Design, and Course 4-B leads to the Bachelor of Science.

Bachelor of Science in Art and Design/Course 4

Course 4 offers a flexible program for students in four possible discipline streams: visual arts; architectural design; building technology; and history, theory, and criticism of architecture and art. Within a clear framework, students develop individual courses of study best suited to their needs and interests.

The requirements for the SB in Art and Design (BSAD) curriculum begin with an introductory subject, 4.101 Experiencing Architecture Studio, designed to be taken by freshmen and sophomores. The remaining core subjects include beginning work in the arts, computation, architectural design, building technology, and the history of architecture and art. Students should discuss their educational interests and plans with a faculty advisor no later than the beginning of the fall term of their junior year. The department has prepared handouts which give the subject requirements for each of its four discipline streams. Each area of concentration provides a variety of subjects from which to choose, as well as an opportunity to get deeply involved in a particular subfield. The Department offers a foreign exchange study program with Delft University of Technology for architecture design seniors in fall term. An optional senior thesis may be taken in the final year.

The vast majority of BSAD candidates choose the architectural design discipline stream, which includes sequential studios. The approach fosters investigation and discussion in the development of sensitivity to the built environment. These sensibilities are linked to values and responsibilities to the community at large. The design studio is a place not only where technical and analytical skills are developed, but a place of synthesis and invention using the elements of architectural form: material, structure, construction, light, sound, memory, and place. This is the process that characterizes the architectural education and what the studio sequence explores.

Students who plan to continue their studies for the graduate degree, Master of Architecture, must apply for admission to the graduate MArch program. Students who have fulfilled the requirements for the Architectural Design discipline stream of the Bachelor of Science in Art and Design normally are able to satisfy the requirements for the MArch in two and one half years if they include in their undergraduate program a sufficient number of professional subjects. This requires careful use of a student’s unrestricted electives.

Eligible BSAD Architectural Design discipline stream students may apply for early admission to the MArch program after the first term of the junior year. If accepted to the MArch program early, students are normally able to satisfy the requirements of the degree in two years of graduate study following successful completion of the BSAD. Consult the department for details.

Students who intend to continue with graduate studies in the visual arts, building technology, and history, theory, and criticism of architecture and art should consult with an appropriate faculty member to design a program of study which establishes the basis for graduate study.
Bachelor of Science/Course 4-B
Course 4-B is offered for students who find that their basic intellectual commitments are to subjects within the Department of Architecture but whose educational objectives cut across departmental boundaries. These students may, with the approval of the department, plan a course of study that meets their individual needs and interests while including the fundamental areas within the department. For example, students might create a coherent program combining subjects in architecture with subjects in urban studies and planning, computer science, systems analysis, acoustics, etc.

As early as possible, students should discuss their interests and intended programs with their advisor and departmental faculty members. A student who wishes to follow Course 4-B must initially register as a Course 4 major. By the end of the sophomore year, the student is expected to submit to the department a proposal that includes a statement of educational goals, a list of subjects to be taken to fulfill these goals (72 units), and a timetable of when the subjects will be taken. When the proposal is approved by the Department of Architecture Undergraduate Curriculum Committee, the student may officially switch to the 4-B major.

The Course 4-B curriculum is similar to Course 4 in that the six core subjects that are to be taken primarily in the freshman and sophomore years are 4.101, 4.104, 4.206, 4.302, 4.401 and 4.605. During the junior and senior years, the approved interdisciplinary course of study is pursued.

Undergraduates in either the Course 4 or Course 4-B major program of the Department of Architecture may, upon consultation with a faculty advisor, exercise flexibility in scheduling completion of the General Institute Requirements. It should be emphasized, however, that any program of studies that involves postponing first-year physics and mathematics limits the possibilities of transferring easily to (or taking advanced subjects in) those departments that presuppose the completion of most of the General Institute Science Requirements by the end of the sophomore year.

### Bachelor of Science in Art and Design/Course 4

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<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
<th>Units</th>
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<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement <a href="6">one subject can be satisfied by a subject in the Departmental Program</a></td>
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<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
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<tr>
<td>Laboratory Requirement</td>
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<tr>
<td>Total GIR Subjects Required for SB Degree</td>
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#### Communication Requirement
The program includes a Communication Requirement of 4 subjects:
- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

#### PLUS Departmental Program
Subject names below are followed by credit units, and by prerequisites if any (coreresquisites in italics)

- **Required Subjects**
  - 4.101 Experiencing Architectural Studio, 12
  - 4.104 Architectural Studio: Intentions, 15, 4.101, CI-M
  - 4.302 BSAD Foundations in the Visual Arts, 12
  - 4.401 Introduction to Building Technology, 12
  - 4.500 Introduction to Design Computing, 12
  - 4.605 Introduction to the History and Theory of Architecture, 12, HASS-D, CI-M

- **Discipline Stream Subjects**
  - By the beginning of their junior year, students are expected to begin concentrating in one of the four discipline streams.
  - **Architectural Design Discipline Stream**
    - 4.125 Architectural Studio: Building in Landscapes, 21; 4.104, 4.302, 4.401, 4.500, 4.605
    - 4.126 Architectural Studio: Building in Cities, 21, 4.125
    - 4.440 Basic Structural Design, 12, REST; 8.02, 18.02
    - plus
    - 4.32 or 4.33 Architectural Design Level II, 21; 4.125, 4.126, 4.440
    - or
    - Two subjects from any of the other three discipline streams, both in the same area

- **Visual Arts Discipline Stream**
  - 4.322 Introduction to Sculpture, 12, HASS; 4.301, 4.302*
  - 4.361 Introduction to Photography and Related Media, 12, HASS; 4.301, 4.302*
  - 4.351 Introduction to Video, 12, HASS; 4.301, 4.302*
    - One intermediate-level subject in Visual Arts
    - One advanced-level subject in Visual Arts
    - plus
    - One of the following subjects:
      - 4.601 Introduction to Art History, 12, HASS-D
      - 4.602 Modern Art and Mass Culture, 12, HASS-D, CI-H
      - 4.614 Religious Architecture and Islamic Cultures, 12, HASS-D
    - plus
    - One additional subject in History, Theory, and Criticism of Art and Architecture

- **Building Technology Discipline Stream**
  - 4.411 Building Technology Laboratory, 12, LAB; 8.02, 18.02
  - 4.421 Fundamentals of Energy in Buildings, 12, REST; 8.01, 18.02
  - 4.440 Basic Structural Design, 12, REST; 8.02, 18.02
    - One additional subject in Building Technology
    - plus
    - 4.425 Architectural Studio: Building in Landscapes, 21; 4.104, 4.302, 4.401, 4.500, 4.605
    - or
    - Two additional subjects in Building Technology
    - plus
    - One additional subject from any of the other three discipline streams.
### Minor Programs

The requirements for a **Minor in Architecture** are as follows:

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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.101</td>
<td>Experiencing Architecture Studio</td>
<td></td>
</tr>
<tr>
<td>4.104</td>
<td>Architecture Studio: Intentions</td>
<td></td>
</tr>
<tr>
<td>4.601</td>
<td>Introduction to the History and Theory of Architecture and either 4.401 Introduction to Building Technology (taken before 4.125) or 4.125 Architecture Studio: Building in Landscapes or Three subjects chosen from the following list: Up to two from: 4.211, 4.250 Up to two from: 4.301, 4.305, 4.322, 4.341, 4.351, 4.366 Up to two from: 4.401, 4.411, 4.421, 4.440, 4.444 Up to two from: 4.500, 4.501, 4.520, 4.522</td>
<td></td>
</tr>
</tbody>
</table>

No more than one from: 4.601, 4.602, 4.605, 4.609, 4.614, 4.615, 4.641, 4.651, 4.652, 4.671, 4.673

The **Minor in the History of Art and Architecture**, considered a HASS minor, is designed to enable students to concentrate on the historical, theoretical, and critical issues associated with art and architectural production. Introductions to the historical framework and stylistic conventions of art and architecture are followed by more concentrated study of particular periods and theoretical problems in visual culture and in cultural history in general.

The minor program consists of six subjects arranged into three levels of study and chosen as follows:

**Tier I**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.601</td>
<td>Introduction to Art History</td>
<td></td>
</tr>
<tr>
<td>4.602</td>
<td>Modern Art and Mass Culture</td>
<td></td>
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</table>

**Tier II**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.606</td>
<td>Visual Perception and Art</td>
<td></td>
</tr>
<tr>
<td>4.613</td>
<td>Civic and Residential Islamic Architecture</td>
<td></td>
</tr>
<tr>
<td>4.614</td>
<td>Religious Architecture and Islamic Cultures</td>
<td></td>
</tr>
<tr>
<td>4.615</td>
<td>The Architecture of Cairo</td>
<td></td>
</tr>
<tr>
<td>4.641</td>
<td>19th-Century Art</td>
<td></td>
</tr>
<tr>
<td>4.645</td>
<td>Selected Topics in Architecture: 1750–Present</td>
<td></td>
</tr>
<tr>
<td>4.651</td>
<td>20th-Century Art</td>
<td></td>
</tr>
<tr>
<td>4.665</td>
<td>Contemporary Architecture and Critical Debate</td>
<td></td>
</tr>
<tr>
<td>4.671</td>
<td>Nationalism, Internationalism, Globalism in Modern Art</td>
<td></td>
</tr>
<tr>
<td>4.673</td>
<td>Installation Art</td>
<td></td>
</tr>
</tbody>
</table>

**Tier III**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.609</td>
<td>Seminar in the History of Art and Architecture or Other advanced seminar in the history of art and/or architecture with permission of the HASS field advisor</td>
<td></td>
</tr>
</tbody>
</table>

For a general description of the minor program, see Undergraduate Education in Part 1.

### GRADUATE STUDY

The Department of Architecture offers five graduate degree programs—the Master of Architecture, Master of Science in Architecture Studies, Master of Science in Building Technology, Master of Science in Visual Studies, and the Doctor of Philosophy.

The Master of Architecture is awarded to students who complete a program, accredited by the National Architectural Accrediting Board,
that is an essential step toward licensure for architectural practice.

The Master of Science in Architecture Studies program stresses research and inquiry in the built environment; the degree is meant both for students who already have their first professional architecture degree and those whose previous education orients them toward nonprofessional graduate study in architecture.

The Master of Science in Building Technology program is run jointly by the Departments of Architecture, Civil and Environmental Engineering, and Mechanical Engineering. It is meant for students who intend to make a career in this field.

The Master of Science in Visual Studies focuses on the development of critical and visionary positions of artistic practice in the context of an advanced technological and scientific community. Central to the curriculum is the potential for creating links with programs in architecture, urbanism, technology, and media studies. Students are challenged to expand their artistic practice by questioning the historical, cultural, social and ethical implications of their work. Discussion in contemporary theory and criticism complements studio production.

The PhD program is an advanced degree program initiated in the area of History, Theory, and Criticism, and has been expanded to the program initiated in the area of History, Theory, and Criticism complements studio production.

The Master of Architecture is awarded upon the satisfactory completion of an approved program of at least 164 units, of which 96 units must be in H-level subjects, and an acceptable thesis. Those who have not yet studied in a department of architecture require three and one-half academic years of residence to fulfill the requirements for the MArch degree.

Advanced standing is possible for students who have taken architectural design at an accredited school of architecture. Students who have majored in architectural design at a “4 plus 2” architecture school, including MIT, may have the time to complete the program reduced to two and one-half or, rarely, even two years depending on their academic experience and accomplishments.

The professional MArch program is seen as being diverse and open-ended with many views of an appropriate theory and practice of architecture available, yet with a general set of shared concerns. These include a commitment to design, a concern for the behavior of people and their participation in creating architecture, an interest in inquiry and criticism, a view of the environment as a living and developing phenomenon, an interest in the relation between the built environment and institutions, a regard for the material processes of building, and a concern for the spatial and temporal contexts of buildings.

Architectural design studios are the center of the MArch degree program. Students must recognize that there are many possible professional roles, and therefore must assume much of the responsibility for structuring their own educational programs. While the professional curriculum specifies that a student study a range of subjects in several interrelated fields, students in the MArch program have some choice within each of the study areas offered in the department, and are required to develop a concentration in a self-determined area.

Master of Science in Architecture Studies

This program is designed to provide a climate for research and inquiry that stresses the investigative component of understanding the built environment. It is open to students with professional degrees in architecture and, more rarely, to other university graduates. The SMArchS degree is awarded upon satisfactory completion of an approved program of study of 96 units, 42 of which will be H-level subjects, and the completion of an acceptable thesis. The degree requires two full academic years of residency.

The program has a strong interest in the methods of inquiry, development and testing of knowledge, and the building and application of theory as it pertains to the built environment. It allows students to specialize in areas in which they wish to obtain particular abilities. There are several areas of study.

In Architecture and Urbanism, areas of faculty interest include theory of urban form and urban design strategies linked to the institutions that effect urban change.

The Aga Khan Program for Islamic Architecture supports a small number of students interested in pursuing research on architecture and urbanism in the Islamic world. Faculty interests include Islamic architectural and urban history and historiography, strategies for preservation, and the critique of contemporary design in Islamic countries.

The mission of Design and Computation is to promote a rethinking of technique in relation to architectural form, as well as to challenge conventional distinctions between physical and virtual environments. Research focuses on new means for describing, representing, and generating architectural form; for modeling physical processes; and for facilitating communication.

Building Technology focuses on the intersection of design and technical issues for buildings that positively contribute to a more humane and environmentally responsible built world. Research within the group addresses innovative materials and assemblies, low-energy strategies, and structures.

A few students can enter the area of History, Theory, and Criticism where they work alongside doctoral students in the study of Western (19th and 20th centuries) architecture and methodological issues that inform or link historical and practical work.

In all these areas, related subjects are available in the Department of Urban Studies and Planning, in other departments at MIT, and at Harvard.

About 60 percent of the students in the SMArchS program come from outside the United States; this encourages the exchange of ideas across cultures. Students often use a site in their home countries as a base for their theses.

Simultaneous Master’s Degrees in Architecture and City Planning

Students who have been admitted to either the Department of Urban Studies and Planning or the Department of Architecture can propose a program of joint work in the two fields that will lead to the simultaneous awarding of two degrees. Degree combinations may be MArch/MCP or SMArchS/MCP. A student must apply by January 1 before beginning the last full year of graduate study for the first degree: SMArchS and MCP students must apply during the spring admissions process. All candidates for simultaneous degrees must meet the requirements of both degrees, but may submit a joint thesis.
Urban Design Certificate
Students in the MCP, MArch, or SMArchS programs who complete a specific curriculum in urban design are awarded a Certificate in Urban Design. The curriculum includes subjects in both Architecture and Planning. For further information, contact Charlotte Liu, Room 10-485, MIT, 617-253-5115.

Master of Science in Building Technology
This program provides a focus for graduate students interested in the development and application of advanced technology for buildings. Students in this program take relevant subjects in basic engineering disciplines along with subjects which apply these topics to buildings. The program is open to qualified students with a degree in engineering or in architecture with a substantial background in technology.

The program concentrates on the development of the next generation of technology for buildings as well as the innovative application of state-of-the-art concepts to building systems. Research programs, in many cases jointly carried out with faculty and students in the School of Engineering, include sustainable building design, controls, natural ventilation and indoor air quality, innovative materials and structures, and computational simulation of building behavior.

The SMBT degree is generally completed in two years, requires 66 units of coursework (42 of which must be H-level graduate credit), and the completion of an acceptable thesis.

Master of Science in Visual Studies
The Visual Arts Program focuses on the development of analytical and visionary strategies in artistic practice within the context of the advanced technological and scientific community of MIT. The program offers an intellectual and studio environment for innovative, experimental, and critical art-making.

Students are challenged to expand their artistic practices through informed and articulate focus on the historical, cultural, social, existential, and ethical implications of their projects. In-depth examination of works in progress, as well as readings and discussions complement artistic production. Workshops, seminars, lectures, project reviews, tutorials, public presentations, and exhibitions are the core of the education method of the program.

Areas of investigation include media art, expanded video, photography, and digital art, as well as public art, performance, sculpture, design, and the art related to science, technology, and technoculture. Central to the curriculum of the program is the capacity for creating links with MIT research units, departments, programs, and centers in architectural design, history, theory, and criticism, urban planning, media arts and sciences, computer science, engineering, and others.

The SMVisS degree is completed in two years, requires 150 units of coursework (105 of which must be H-level graduate credit), and the completion of an acceptable thesis.

Doctor of Philosophy
The PhD in Architecture may be pursued in one of four separate areas: (1) History and Theory of Architecture, (2) History and Theory of Art, (3) Building Technology, or (4) Design and Computation.

The PhD program in the area of History, Theory, and Criticism of Architecture and Art emphasizes the study of Western (19th and 20th centuries) and Islamic art, architecture and urbanism, and methodological issues that inform or link historical and practical work.

The doctoral program in Building Technology is interdepartmental, with important components in the Departments of Civil and Environmental Engineering and Mechanical Engineering. Research programs include sustainable building design, controls, natural ventilation and indoor air quality, innovative materials and structures, and computational simulation of building behavior.

The PhD program in Design and Computation is broadly conceived around computational ideas and digital technologies as they pertain to the understanding, description, generation, and construction of architectural form. Research topics include the mathematical foundations of shape and shape representation; generative tools for design synthesis; advanced modeling and visualization techniques; rapid prototyping and CAD/CAM technologies for physical fabrication; and the analysis of the design process and its enhancement through supporting technologies and work spaces. The mission of the program is to enrich design from a computational perspective, with clear implications for teaching and practice.

Admission and degree requirements vary somewhat in the specific areas listed above, and may be obtained from the Department of Architecture headquarters, or in correspondence with the separate areas. The residency requirement for the PhD is a minimum of two full academic years. However, advanced standing awarded at admission may reduce this to three terms for students with a prior MIT degree. Completion of all of the requirements for the PhD—including the dissertation—is usually accomplished in five years.

Each student admitted to work for the PhD should consult closely with one principal professor in his or her area to develop a general plan of study. In all three areas, progress toward the PhD follows a sequence of required subject work, qualifying papers, general examinations, and dissertation research, writing, and defense. Students are encouraged to take subjects appropriate to their study plans in other departments at MIT, and at Harvard.

Inquiries
Further information concerning undergraduate and graduate academic programs in the department, admissions, financial aid, and assistantships may be obtained from the Department of Architecture, Room 7-337, MIT, 617-253-7387, or by visiting http://architecture.mit.edu/.

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Head of Department

Professors
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Professor of History and Architecture
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Professor of Architecture
John de Monchaux, MArch
Professor of Architecture and Urban Planning
Michael Dennis, BArch
Professor of Architecture
John Randolph Myer, BArch  
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Otto Piene, MA  
Professor of Visual Design, Emeritus

Maurice Keith Smith, BArch  
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Chester Lee Sprague, MArch  
Associate Professor of Architecture, Emeritus

Waclaw Piotr Zalewski, DTechSci  
Professor of Structures, Emeritus
The Program in Media Arts and Sciences (MAS) focuses on the invention, study, and creative use of new technologies that change how we express ourselves, how we communicate with each other, how we learn, and how we perceive and interact with the world. The field draws on a number of other disciplines, including computer science, cognitive sciences, communications, design, and the expressive arts. The program offers undergraduate and graduate subjects (listed under MAS in Part 3) and a graduate program leading to master’s and doctoral degrees. Its academic programs are intimately linked with the research programs of the Media Laboratory.

UNDERGRADUATE STUDY

Most MAS undergraduate courses are project-oriented and relate to ongoing research within the Media Laboratory. Certain graduate subjects are open to advanced undergraduates (see subject descriptions in Part 3 for details).

Undergraduate Research Opportunities Program (UROP) positions at the Media Lab are a major part of the MAS education offerings to undergraduates. First-year students participating in UROP are encouraged to register for MAS.111 Introduction to Research in Media Arts and Sciences.

The MAS Alternative Freshman Year Program emphasizes project-oriented work and connections to current research topics. Students in this program attend mainstream lectures for core freshman subjects but take recitations led by Media Laboratory researchers and participate in research through UROP positions at the Media Lab.

GRADUATE STUDY

Media Arts and Sciences offers a graduate program leading to master’s and PhD degrees. Graduate students work closely with a research advisor in an apprenticeship relationship. Students enter the program from a wide variety of backgrounds, including electrical engineering, physics, computer science, cognitive science, mechanical engineering, art and design, and the learning sciences.

For the master’s degree, students are required to spend at least four terms in residence (one of which may be a summer term) and to complete a satisfactory research thesis.

Students wishing to pursue a PhD degree must demonstrate exemplary progress in the master’s program and gain approval from a departmental committee review. Requirements for the PhD degree include successful completion of MAS general exams, and successful completion and defense of a dissertation based on original and significant research within one of the Media Lab’s research groups.

Research Assistantships

The Program in Media Arts and Sciences offers financial assistance to all successful applicants in the form of research assistantships within the Media Laboratory, which are an important part of the educational program. Research assistants receive academic credit for part of their research activities.

Inquiries

Additional information about the programs in Media Arts and Sciences, graduate admissions, research programs, and research assistantships may be obtained from Pat Solakoff, MIT, 20 Ames Street, Room E15-401, Cambridge, MA 02139-4307; telephone 617-253-5114, fax 617-253-8542, email mas@media.mit.edu.

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LEGO Papert Career Development Professor of Learning Research

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Asahi Broadcasting Corporation Career Development Professor of Research in Education

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Associate Professor of Media Arts and Sciences

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Rudge (1948) and Nancy Allen Professor of Media Arts and Sciences

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Associate Professor of Media Arts and Sciences

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Joseph Paradiso, PhD
Associate Professor of Media Arts and Sciences

Sony Corporation Career Development Professor of Media Arts and Sciences
Ted Selker, PhD  
Associate Professor of Media Arts and Sciences  
Benesse Career Development Professor of  
Research in Education

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Andrew Lippman, PhD

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V. Michael Bove, Jr., PhD  
Glorianna Davenport, MA  
Christopher Schmandt, MSVS

Research Associates/Scientists  
David Cavallo, PhD  
Henry Lieberman, PhD

Professors Emeriti  
Marvin Minsky, PhD  
Professor of Media Arts and Sciences, Emeritus  
Seymour Papert, PhD  
Professor of Education and Media Technology, Emeritus
The Department of Urban Studies and Planning (DUSP) offers several degree and nondegree programs: Bachelor of Science in Planning; Master in City Planning (MCP); Master of Science in Urban Studies and Planning; Doctorate in Urban Studies and Planning; the Special Program in Urban and Regional Studies (for mid-career professionals from less developed areas); the Center for Reflective Community Practice (for mid-career professionals from communities of color in the United States); the Urban Design Certificate, offered jointly with the Department of Architecture; and special student status for part-time mid-career professionals interested in taking individual subjects.

City and regional planners in the United States and other parts of the world are involved not only in physical and economic development, but also in management of the environmental, social, and design consequences of development. They engage in a variety of activities aimed at shaping the pattern of human settlements, and at providing people with housing, public services, employment opportunities, and other crucial support systems that comprise a decent living environment. Planning encompasses not just a concern for the structure and experience of the built environment, but also a desire to harness the social, economic, political, and technological forces that give meaning to the everyday lives of men and women in residential, work, and recreational settings. Planners operate at the neighborhood, metropolitan, state, national, or international level, in both the public and the private sectors. Their tasks are the same: to help frame the issues and problems that receive attention; to formulate and implement projects, programs, and policies responsive to individual and group needs; and to work with and for various communities in allocating economic and physical resources most efficiently and most equitably.

Planners are often described as "generalists with a specialty." The specialties offered at MIT include city design and development; housing, community, and economic development; international development; and environmental policy and planning, as well as cross-cutting opportunities to study urban information systems and transportation. These planning specialties can be distinguished by the geographic levels at which decision making takes place—neighborhood, city, region, state, national, and global. Subspecialties have also been described in terms of the roles that planners are called upon to play, such as manager, designer, regulator, advocate, educator, evaluator, or futurist. The Department of Urban Studies and Planning is committed to educating planners who can advocate on behalf of underrepresented constituencies.

A focus on the development of practice-related skills is central to the department's mission, particularly for students in the MCP professional degree program. Acquiring these skills and integrating them with classroom knowledge are advanced through the department's field-based practicum subjects and research, and through internship programs. In fieldwork, students acquire competence by engaging in practice and then bringing field experiences back into the academic setting for reflection and discussion. Students may work with community organizations, government agencies, or private firms under the direction of faculty members involved in field-based projects with outside clients. In some cases, stipends may be available for fieldwork or internship programs.

During the month of January, the Department of Urban Studies and Planning offers a series of "mini-subjects" in specialized fields not covered by the regular curriculum, including both non-credit and for-credit offerings.

Specific opportunities for concentration and specialization available to students are detailed in the descriptions of the degree programs that follow.

**UNDERGRADUATE STUDY**

The Department of Urban Studies and Planning offers a Bachelor of Science in Planning, a HASS Minor in Urban Studies and Planning, a HASS Minor in Public Policy, and a variety of HASS concentrations. There is also an accelerated SB/MCP program which allows exceptional students to complete their undergraduate and master's degree work in five years.

DUSP also hosts MIT's Teacher Education Program (TEP), described in the section on Career and Professional Options in the Undergraduate Education chapter in Part 1. TEP provides an option for students interested in exploring new ideas in teaching and learning as applied to K-12 schools. Studies in TEP can also lead to licensure in math or science teaching at the high school or middle school levels.

**Bachelor of Science in Planning/ Course 11**

The Department of Urban Studies and Planning offers an interdisciplinary preprofessional undergraduate major designed to prepare students for careers in both the public and the private sectors. The major also provides a foundation for students intending to do graduate work in law, public policy, development, urban design, management, and planning itself. The subjects in the major teach students the ways in which the tools of economics, policy analysis, political science, and design can be brought to bear on critical social and environmental problems in the United States and abroad. In addition, students learn the special skills and responsibilities of planners who seek to promote efficient and equitable change.

After satisfying the core requirements listed below, students must use their electives to pursue a specific track. We suggest one of the following, but will accept self-designed options to better meet a student's interest: urban and environmental policy and planning; urban society, history, and politics; or urban and regional public policy. The required laboratory emphasizes urban information systems and offers skills for measurement, representation, and analysis of urban phenomena common to these areas. In the laboratory subject, students also explore the ways in which emerging technology can be employed to support better government decision making.

Students are encouraged to develop a program that will strengthen analytic skills and broaden their intellectual perspectives, on the one hand, yet will test these insights in real-world applications, on the other. Students must undertake a senior project that synthesizes what they have learned. Such a project may be a focused analysis of a policy issue, a report on a problem-solving experience from an internship, other fieldwork, or social science research on urban affairs.
Five-Year SB-MCP Option
MIT undergraduate majors may apply for admission to the department’s Master in City Planning Program in their junior year. Students accepted into the five-year program receive both the Bachelor of Science and the Master in City Planning at the end of five years. Admission is limited to those undergraduates who have demonstrated exceptional professional promise. More information on the five-year program can be obtained from Sandra Wellford, undergraduate administrator, Room 7-346A, MIT, 617-253-9403.

Minor Program in Urban Studies and Planning
The six-subject Minor in Urban Studies and Planning offers students the opportunity to explore issues in urban studies and planning in some depth. Students initially take two Tier I subjects that establish the government, economic, and urban design contexts for local, urban, and regional decision making. Next, students choose three Tier II elective subjects, which provide an opportunity to focus on urban and environmental policy issues or to study urban problems and institutions. Where undergraduate electives are unavailable in the student’s field of interest, the student may choose from a variety of graduate courses, subject to the instructor’s permission. Finally, students take 11.123 Big Plans, which aims at a reflective synthesis of past and present efforts to implement large projects and policies. Students are encouraged to craft a minor that reflects their own particular interests within the general parameters of the minor program requirements and in consultation with the minor advisor.

Bachelor of Science in Planning/Course 11

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement [four subjects can be satisfied by subjects in the Departmental Program]</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Laboratory Requirement [can be satisfied by 11.188 in the Departmental Program]</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td>17</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication Requirement</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>The program includes a Communication Requirement of 4 subjects:</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2 subjects designated as Communication Intensive in the Major (CI-M).</td>
<td>2</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>PLUS Departmental Program</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Required Subjects</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>All of the following:</td>
<td>57</td>
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</tr>
<tr>
<td>11.001 Introduction to Urban Design and Development, 12, HASS</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>11.002 Making Public Policy, 12, HASS-D, CI-H</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>11.123 Big Plans, 9, HASS</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>14.01 Principles of Microeconomics, 12, HASS</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>11.188 Urban Planning and Social Science Laboratory, 12, LAB, CI-M</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Planned Electives</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Majors in Course 11 are required to formulate or select one stream of coursework for concentration.</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>They can select from the following recommended options or create their own stream tailored to a particular set of urban, policy, or planning concerns.</td>
<td>57</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Urban and Environmental Policy and Planning</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.011 The Art and Science of Negotiation, 12, HASS</td>
<td>12</td>
<td></td>
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<tr>
<td>11.014 American Urban History II, 9, HASS</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>11.016 The Once and Future City, 12, HASS, CI-H</td>
<td>12</td>
<td></td>
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<tr>
<td>11.026 Downtown, 9, HASS</td>
<td>9</td>
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<tr>
<td>11.102 Theories of Economic Development, 12, HASS; 14.01, 14.02</td>
<td>14</td>
<td></td>
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<tr>
<td>11.112 Society and Environment, 12, HASS</td>
<td>12</td>
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<tr>
<td>1.011 Project Evaluation, 9</td>
<td>9</td>
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<tr>
<td>1.041 Engineering System Design, 12, 1.011</td>
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<tr>
<th>Urban Society, History, and Politics</th>
<th>Subjects</th>
<th>Units</th>
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<tbody>
<tr>
<td>11.013 American Urban History I, 9, HASS</td>
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<td>11.014 American Urban History II, 9, HASS</td>
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<tr>
<td>11.015 Riots, Strikes, and Conspiracies in American History, 12, HASS-D, CI-H</td>
<td>12</td>
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<td>11.020 Poverty, Public Policy, and Controversy, 12, HASS</td>
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<td>11.021 Bridging Cultural and Racial Differences, 12, HASS</td>
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<td>11.024 Great Cities, 9, HASS</td>
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<td>11.026 Downtown, 9, HASS</td>
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<tr>
<td>11.102 Theories of Economic Development, 12, HASS; 14.01, 14.02</td>
<td>14</td>
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<tr>
<td>11.130 Theory of City Form, units arranged; 11.001</td>
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<tr>
<th>Urban and Regional Public Policy</th>
<th>Subjects</th>
<th>Units</th>
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<tr>
<td>11.003 Methods of Public Policy Analysis, 12, HASS; 11.002, 17.30, 14.02</td>
<td>17</td>
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<tr>
<td>11.011 The Art and Science of Negotiation, 12, HASS</td>
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<td>11.020 Poverty, Public Policy, and Controversy, 12, HASS</td>
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<td>11.025 D-Lab: Development, 12</td>
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<td>11.102 Theories of Economic Development, 12, HASS; 14.01, 14.02</td>
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<td>11.126 Economics of Education, 12, HASS; 14.01</td>
<td>14</td>
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<tr>
<td>11.166 Law, Social Movements, and Public Policy, 12, HASS</td>
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<tr>
<th>Urban Field Experience</th>
<th>Subjects</th>
<th>Units</th>
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<tbody>
<tr>
<td>Declared majors are encouraged to take the optional urban field experience subject.</td>
<td>12</td>
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<tr>
<td>11.027 City to City (CI-M) is taught in the spring and includes a trip during spring break. This course may be taken multiple times, as the content differs each year, but may only be counted once as a planned elective.</td>
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<tr>
<th>Thesis</th>
<th>Subjects</th>
<th>Units</th>
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<tr>
<td>Majors are required to write a senior thesis or complete a senior project. The thesis/project writing process is accompanied by a required undergraduate thesis preparation seminar, which meets in the fall.</td>
<td>12</td>
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<tr>
<td>11.1Th Thesis Research Design Seminar, 12, CI-M</td>
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<tr>
<td>11.1ThU Undergraduate Thesis Seminar and Thesis, 12</td>
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Minor Program in Public Policy

Public policy is an academic field that focuses on how government action can be best utilized to enhance the quality of life of citizens. The interdisciplinary HASS Minor in Public Policy is intended to provide a single framework for students in engineering and sciences who are interested in the role of public policy in the field of their technical expertise. The six-subject minor is organized along three dimensions.

The first dimension is a foundation built on the study of market and nonmarket institutions in which public policy decisions are made and implemented. All students take two subjects that introduce them to justifications for government action—justifications that form the fundamental basis for making public policy. The second is the study of the methodologies of analyzing and assessing the impacts of policy change on policy outcomes. The purpose is to provide a basic level of competence so that students are knowledgeable about the range of approaches that professionals use to analyze public policies. The third is an in-depth study of policymaking in one substantive field. All minors select an area of public policy specialty, such as science and technology policy, and take three subjects within that area of specialty. Students also have the possibility of doing an internship in order to fulfill one part of the three-subject requirement. Course 11 majors are not eligible for the public policy minor. Additional information can be obtained from Sandra Wellford, undergraduate administrator, Room 7-346A, MIT, 617-253-9403.

Tier I
11.002J/17.30J Making Public Policy
11.024 Great Cities
11.102J Theories of Economic Development
11.125 Downtown
11.166 Law, Social Movements, and Public Policy

Tier II
11.023 Bridging Cultural and Racial Differences
11.025 D-Lab: Development

Tier III
11.123 Big Plans

Graduate Study

The Department of Urban Studies and Planning offers graduate work leading to the Master in City Planning and the Doctor of Philosophy. In conjunction with the Center for Real Estate, the department also offers a Master of Science in Real Estate Development. These programs are open to students from a variety of backgrounds. Urban studies, city planning, architecture, urban design, environmental planning, political science, civil engineering, economics, sociology, geography, law, management, and public administration all offer suitable preparation. For further information concerning academic programs in the department, application for admission, and financial aid, contact Graduate Admissions, Room 7-346, MIT, 617-253-9403.

Master in City Planning

The principal professional degree in the planning field is the Master in City Planning (MCP). The Department of Urban Studies and Planning provides graduate education for men and women who will assume professional roles in public, private, and nonprofit agencies, firms, and international institutions, in the United States and abroad. The department seeks to provide MCP students with the skills and specialized knowledge needed to fill traditional as well as emerging planning roles. The MCP is accredited by the American Planning Association.
The two-year Master in City Planning Program emphasizes mastery of tools for effective practice and is therefore distinct from undergraduate liberal arts programs in urban affairs. In addition to its basic core requirements, the program offers four areas of specialization: city design and development; environmental policy and planning; housing, community, and economic development; and international development and regional planning. MCP students, in their application to the department, select one of these areas of specialization.

A first-year student’s plan of study in the MCP Program is set forth in a program statement developed jointly by the student and faculty advisor after the student’s first term. The program statement describes the purposes and goals of study, the proposed schedule of subjects, the manner in which competence in a specialization is developed, and an indication of a possible thesis topic.

**Degree Requirements.** Students are expected to take a minimum of 36 credit units each term (about three subjects), yielding at least 126 total units, in addition to the thesis.

A collection of subjects and requirements to be taken during the student’s two years in the MCP program constitute a “core experience” viewed as central to the professional program. The core subjects and requirements include the following:

- Students must also complete at least one core practicum subject, selected from an approved list, during the two-year program.
- Students identified as having writing issues are encouraged to take a writing course.

Students are required to take an introductory subject to their chosen specialization area in the first term of the freshman year. During the fall of the second year, students must take a thesis preparation seminar in their area of specialization.

The City Design and Development group is concerned with shaping the built and natural environment of cities and suburbs. Graduates work in a variety of private, public, and non-profit roles: as developers, planning and design consultants, municipal and regional planners, managers of public programs to improve the environment, advocates of historic preservation and public art, and planners of transportation systems. The group is closely associated with faculty and students in the Department of Architecture and the Center for Real Estate, and many subjects are cross-listed with these programs.

While the educational offerings are diverse and every student can develop unique competence in the area, there are at least three clusters of skills in city design and development: land use planning, for those who wish to work as municipal planners or consultants, or wish to be involved in planning large-scale development projects in the United States and abroad; urban design, for those who wish to be involved in shaping the public realm; and urban development, for those who wish to manage development projects for private or public sector organizations.

The Environmental Policy and Planning group emphasizes the study of the ways in which society conserves and manages its environmental resources. Areas of concern include the role of science in environmental policy making, sustainable development and adaptive ecosystem management, brownfields redevelopment, environmental justice, global environmental treaty making, environmental regulation, and the mediation of environmental disputes.

Students examine the interactions between built and natural systems, techniques for describing and evaluating changes in environmental quality, approaches to environmental policy analysis, strategies for stakeholder involvement in environmental planning, and mechanisms for assessing the choices posed by the environmental impacts of new technology in local, state, national, and international contexts.

The Housing, Community, and Economic Development (HCED) group focuses on the design, location, organization, and financing of housing, economic, and community development programs and the capital and labor markets that impact such development at the local level. Specifically, the group is concerned with understanding how public policy and private markets affect housing, economic development, and the local economy; employing techniques for assessing community needs, including housing, community services facilities, and sources of jobs; and developing and implementing programs, policies, and strategies that are directed at meeting these needs. HCED places a strong emphasis on practice and effective action at the state, local, and neighborhood levels and emphasizes that strategic analysis of the institutional context within which action occurs is central to such effectiveness.

The International Development (ID) group draws on the experiences of developing and newly industrializing countries throughout the world as the basis for advice about planning at the local and regional levels. ID provides students with an integrated view of the institutional, historical, economic, technological, and socio-political factors that have shaped successful planning experiences, and how they translate into action. Class content and faculty expertise include local and regional economic development, regional planning (including decentralization), finance, and project evaluation; housing, human settlements, and infrastructure services (transportation, telecommunications, water, sewerage); institutions of economic growth and industrialization and industrial policies (including privatization); and poverty-reducing and employment-increasing interventions, including informal sector, nongovernment organizations, and small enterprises; comparative urban and regional policy; property rights, collective action and common property issues (water, forestry, grazing, agriculture), and human rights.

Urban Information Systems (UIS) is a cross-cutting group that connects faculty, staff, and students through their shared interests in how information and communication technologies impact urban planning. Some are studying the complex relationships underlying urban spatial structure, land use, transportation, and environmental interactions. Others are building neighborhood information systems, modeling urban futures, facilitating public participation in planning processes, or experimenting with e-neighbors, community building, and the formation of social capital.

Much of UIS’s work involves the development and use of planning-related software and the spatial analysis tools and systems (such as GIS and distributed geoprocessing) that are increasingly important parts of metropolitan informa-
tion infrastructures. However, UIS interests go beyond the development and use of specific technologies and extend to an examination of the ripple effects of computing, communications, and digital spatial information on current planning practices and on the meaning and value of the impacted communities and planning institutions.

All students are required to submit a thesis on a topic of their choice. The department encourages MCP students to avoid the traditional perception of the thesis as a “mini-dissertation,” and to think instead of a client-oriented, professional document that bridges academic and professional concerns. While most of the thesis work occurs during the last term of the second year, students are urged to begin the process of defining a thesis topic early in the second year through their participation in a required thesis preparation seminar.

Students in the MCP Program are encouraged to integrate fieldwork and internships with academic coursework. The Department of Urban Studies and Planning provides a variety of individual and group field placements involving varying degrees of faculty participation and supervision. Academic credit is awarded for field experience, although some students choose instead to participate in the work-study financial aid program. The department also sponsors a variety of seminars in which students have an opportunity to reflect on their field experiences.

**Simultaneous Master’s Degrees in City Planning and Architecture**

Students who have been admitted to either the Department of Urban Studies and Planning or the Department of Architecture can propose a program of joint work in the two fields that will lead to the simultaneous awarding of two degrees. Degree combinations may be MCP/MArch or MCP/SMArchS. A student must apply by the January deadline prior to beginning the last full year of graduate study for the first degree: MCP and SMArchS. Students must apply during their first year at MIT (by the end of the first term); MArch students must apply during or before their second year. Students are first approved by the Dual Degree Committee and then considered during the spring admissions process. All candidates for simultaneous degrees must meet the requirements of both degrees, but may submit a joint thesis.

**Simultaneous Master’s Degrees in City Planning and Transportation**

Students who have been admitted to study for the Master in City Planning or the Master of Science in Transportation may apply to the other program during their first year of study and propose a program of joint work in the two fields that will lead to the simultaneous awarding of two degrees. Details of this program are provided in the section on the Center for Transportation Systems Division in Part 2.

**Simultaneous Master’s Degrees in City Planning and Real Estate Development**

Students who have been admitted to the Master in City Planning Program or the Master of Science in Real Estate Development Program may apply to the other program during their first year of study and propose a program of joint work in the two fields that will lead to the simultaneous awarding of two degrees. Information on this program is given under the section on the School of Architecture and Planning. Students may submit a joint thesis.

**Master of Science in Urban Studies and Planning**

Under special circumstances, admission may be granted to candidates seeking the Master of Science degree. The general requirements for the SM degree are given in Part 1. In addition, the department requires a letter from a DUSP faculty member indicating willingness to advise the thesis. The letter should be included with the application. For further information concerning the SM option, contact Graduate Admissions, Room 7-346, 617-253-9403.

**Urban Design Certificate**

Students in the MCP, MArch, or SMArchS program who complete a specific curriculum of subjects in the Urban Studies and Planning and Architecture departments are awarded a Certificate in Urban Design. For further information contact the CDD office, Room 10-485, MIT, 617-253-5115.

**Doctor of Philosophy**

The PhD is the advanced research degree in planning or urban studies. Admission requirements are substantially the same as for the master’s degree, but more emphasis is placed on academic preparation and the fit between the student’s research interests and the department’s research activities.

The doctoral program emphasizes the development of research competence and flexibility in exploring questions that no single academic discipline can answer. Students work under the mentorship of a faculty advisor. They may center their activities on any subfield in which the faculty have expertise.

After successful completion of coursework, students are required to take oral and written general exams in two fields: a broad intellectual discipline (city design and development, international development economics, public policy, planning information systems, urban and regional economics, or urban sociology) and an area to which this discipline applied and which coincides with the student’s research interest. Doctoral candidates are expected to complete general examinations before beginning their third year of residence. Upon completing the general examination, a PhD candidate must write a doctoral dissertation that gives evidence of the capacity to do independent and innovative research.

A minimum of 72 units (for students with a master’s degree), plus 36 units for the dissertation (a minimum of 108 units) is required for the PhD degree.

Interested and qualified students can undertake joint doctoral programs with the Department of Political Science or the Department of Economics.

**Nondegree Programs**

A limited number of nondegree students are admitted to the department each term. This special student status is especially designed for professionals interested in developing specialized skills, but is also available to others.

The Center for Reflective Community Practice (CRCP) promotes social justice by expanding access to and engagement with the knowledge developed by people working on the ground in disenfranchised, low-income communities. CRCP aims to both empower and learn from those indi-
individuals, who, in the face of injustice, inequality, and exclusion, have dedicated themselves to making their communities healthier and more vibrant places to live. The knowledge that is formed in the face of struggles to create lasting change, by those who are least served by society, is significant, sophisticated, and essential for framing and solving today’s most urgent social problems.

By focusing its efforts on helping community practitioners “know what they know,” CRCP has successfully supported resident-directed change in underserved communities across the United States since 1998. Today CRCP hosts a variety of projects and guides the community-based work of up to 20 fellows each year. CRCP advances the use of practitioner and community knowledge through three strategic pathways:

1. Identifying, documenting, and organizing practitioner and community knowledge developed through on-the-ground social justice work.
2. Building opportunities and practical methods for community practitioners to use to engage their peers and others they wish to influence with the knowledge arising from their community practice.
3. Analyzing and communicating the value and merits of practitioner and community knowledge to broad audiences.

CRCP is located in Room 7-307. Further information can be found on the CRCP website at http://crcp.mit.edu/, by emailing crcp@mit.edu, or calling 617-253-3216.

The Special Program for Urban and Regional Studies of Developing Areas (SPURS) provides an opportunity for a small number of highly qualified mid-career professionals from developing countries to spend a year at MIT studying the problems of urban and regional change in the broad context of international development. SPURS is an intentionally flexible program, offering the option of a nondegree or an MS degree program. For further information contact Nimfa DeLeon, SPURS, Room 10-400, MIT, 617-253-5915 or visit http://web.mit.edu/spurs/www/.

**FACULTY AND STAFF**

**Faculty and Teaching Staff**

Lawrence Vale, SMArchS, DPhil
Professor of Urban Design and Planning
MacVicar Faculty Fellow
Head of Department

**Professors**

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Brian A. Ciochetti, PhD
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CRE Eastman Chair
Phillip Clay, PhD
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Chancellor, MIT
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Professor of Political Sociology
Associate Dean, School of Architecture and Planning
John de Monchaux, MArch
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(On leave, spring)
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David Geltner, PhD
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Director, Center for Real Estate
Langley C. Keyes, PhD
Ford Professor of City and Regional Planning Chair, MCP Committee
Frank Levy, PhD
Daniel Rose Professor of Urban Economics Chair, PhD Program

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Director, Center for Reflective Community Practice
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NTU Professor of Human Resources and Management
Deputy Dean, MIT Sloan School of Management
Karen R. Polenske, PhD
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Director, Special Program for Urban and Regional Studies in Developing Countries
J. Mark Schuster, PhD
Professor of Urban Cultural Policy
Anne Spirn, MLA
Professor of Landscape Architecture and Planning
Lawrence E. Susskind, MCP, PhD
Ford Professor of Urban and Environmental Planning
Judith Tendler, PhD
Professor of Political Economy
William C. Wheaton, PhD
Professor of Urban Economics

**Associate Professors**

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Associate Professor of Landscape Architecture and Planning
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JoAnn Carmin, PhD
Charles H. and Ann Spaulding Career Development Associate Professor of Environmental Policy and Planning
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Xavier de Souza Briggs
Associate Professor of Community Development and Public Policy
Eric Klopfer, PhD
Joseph R. and Rita P. Scheller Career Development Associate Professor of Education
Director, Teacher Education Program
(On leave)
Balakrishnan Rajagopal, SJD
Ford International Career Development Associate Professor of Law and Development

Carlo Ratti, PhD
Associate Professor of Practice
Director, SENSEable City Lab

J. Phillip Thompson, PhD
Associate Professor of Urban Politics and Community Development

**Assistant Professors**

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Annette Kim, PhD
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Judith Layzer, PhD
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Chair, Undergraduate Program

**Adjunct Professors**

Richard Sennett, PhD
Bemis Adjunct Professor of Sociology and Urban Studies

Terry Szold, MRP
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Karl Seidman, MPP

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Paula Anzer, MCP
James Hamilton, SM
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Rhonda Ryznar, PhD

Gloria Schuck, PhD
Susan Silberberg, MCP

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Carlo Ratti, PhD

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Visiting Scholar

Manuel Castells, PhD
Distinguished Visiting Professor of Sociology and Planning

Lois Craig, BA
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Tali Hatuka, PhD
Postdoctoral Fellow

Herman Karl, PhD
Visiting Lecturer

Sam Bass Warner, PhD
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Gary Hack, MArch, MUP, PhD
Professor of Urban Design, Emeritus

Frank Jones, MBA
Ford Professor of Urban Affairs, Emeritus

Melvin H. King, MEd
Director, Community Fellows Program, Emeritus

Tunney F. Lee, BArch
Professor of Architecture and Urban Studies and Planning, Emeritus

Gary Marx, PhD
Professor of Sociology, Emeritus

Lisa Redfield Peattie, PhD
Professor of Urban Anthropology, Emerita
Senior Lecturer

Clarence G. Williams, PhD
Adjunct Professor of Urban Studies and Planning, Emeritus
Leadership through Technical Excellence and Innovation

The primary objectives of the School of Engineering at MIT are to educate and prepare men and women for leadership in industry, government, and educational institutions; to prepare them for purposeful and thoughtful creation and utilization of knowledge and technology to improve the human condition; to advance the knowledge base of engineering; to advance the knowledge base of the engineering professions; and to influence the future directions of engineering education and practice.

The educational programs in the School emphasize the understanding of fundamental principles; facility with experimental, computational, and analytical methods; development of skill in the creative processes of engineering, such as design; development as individuals and professionals; and the development of a self-confidence and versatility of mind that prepare the individual for a lifetime of learning and professional growth.
By creating, developing, organizing, and managing complex technologies and products, engineers play a crucial role in contributing to the betterment of humanity and in shaping our world. Seeking solutions to the most difficult challenges of our day in the context of physical, economic, human, political, legal, and cultural realities makes engineering a tremendously exciting endeavor. In a world increasingly influenced by scientific and technological innovation, engineers can provide important leadership to society.

Technology’s enormous influence on society has created a large demand for engineering graduates, not only to enter the professional practice of engineering, but to bring the strengths of an engineering education to related fields such as law, medicine, management, and government. Never have the challenges and opportunities for careers in engineering been more exciting or more critical to the long-term well-being of society than they are today.

The first-year curriculum for undergraduates includes physics, chemistry, mathematics, biology, and the humanities, arts, and social sciences. An undergraduate student normally becomes affiliated with a particular department at the beginning of the sophomore year and works closely with an advisor from that department or program. A student who would like to explore engineering as a major is encouraged to become involved with one of the engineering departments as early as the freshman year. Nearly every engineering department offers exciting subjects that introduce engineering to freshmen. Freshman Advising Seminars bring students together in small groups with engineering faculty. Undergraduate Research Opportunities Projects (UROPs) are a great way to delve into cutting-edge engineering research. Extracurricular clubs, such as the MIT Rocket Team or the Solar Electric Vehicle Team, offer students hands-on engineering design experiences.

Once a student chooses an undergraduate major, there are many opportunities for individual initiatives. For example, a significant number of students combine their primary undergraduate degrees with a second undergraduate degree in another area, such as management, political science, economics, one of the sciences, or another area of engineering. Others organize their programs so that they can receive undergraduate and graduate degrees simultaneously. A series of minor programs from across the Institute is also available.

Pioneering Programs in Engineering Education
Engineering education has been at the core of the Institute’s mission since its founding in 1861. MIT created the contemporary model of engineering education grounded in a dynamic, changing base of science; and pioneered the modern model of the research university, with externally sponsored research programs and a matrix of academic departments and research laboratories working across disciplines. MIT also created entire new fields, for example, chemical engineering, sanitary engineering, naval architecture and marine engineering, and the first course in aeronautical engineering. Today, the School of Engineering is responding with new degree programs to the molecular and genomic revolutions that have made biology a foundational science for engineering.

The School has distinguished itself as a leader in engineering education, teaching applied, hands-on engineering. In 1916, it created one of the first industrial internship programs, now the David H. Koch School of Chemical Engineering Practice. In recent times, the School of Engineering has launched numerous pioneering programs, many with industry, such as Leaders for Manufacturing (1988); System Design and Management (1997); Project iCampus (1999); and in 2001, the Deshpande Center for Technological Innovation and the Undergraduate Practice Opportunities Program (UPOP). UPOP is described below.

In addition to major initiatives and programs, the School of Engineering is constantly innovating in engineering education, developing novel pedagogical approaches, designing new subject offerings that strengthen current programs, and creating new disciplines, fields of study, majors, and graduate programs. Two examples are the relatively new SB in Chemical-Biological Engineering—MIT's first undergraduate engineering degree with modern molecular biology as its core science; and, begun in 2005–2006, the SB in Biological Engineering program—the first entirely new curriculum established at the Institute in 29 years. Five other new degree programs have been launched in the past five years: the SB in Mechanical and Ocean Engineering, MEng in Manufacturing, SM in Computation for Design and Optimization, PhD in Computational and Systems Biology, and PhD in Engineering Systems.

Because of its unique role in technological innovation, the School of Engineering is also the home of the Lemelson-MIT Program. Established in 1994, the program is a nationwide educational initiative whose mission is to generate excitement about invention, innovation, and entrepreneurship through its annual awards and its outreach activities. The program awards the prestigious $500,000 Lemelson-MIT Prize for Invention, the Lemelson-MIT Lifetime Achievement Award, and the $30,000 Lemelson-MIT Student Prize. In addition to granting these awards, the program instituted InvenTeam grants to support a non-competitive, team-based approach to invention and innovation among high school students.

The latest addition to the School of Engineering is its Office of Professional Education Programs (PEP), created in 2002 from the former Center for Advanced Educational Services (formerly the Center for Advanced Engineering Study) and the former Professional Institute. PEP is an umbrella organization for activities associated with lifelong learning. Its programs are described in Part 1 in the section Interdisciplinary Research and Study.

Today, nearly all of the School’s departments are ranked at the top of their respective fields. Its seven academic departments and two divisions are home to the School’s 370 faculty members, slightly over one-third of the Institute’s total faculty. Among the most distinguished in the nation, members of the School’s faculty and research staff constitute approximately five percent of the membership of the National Academy of Engineering.

Over 55 percent of MIT undergraduates with declared majors and more than 45 percent of all graduate students are in the School of Engineering.

Interdepartmental Research Programs
Within the School of Engineering, a student may develop a program that satisfies his or her own intellectual and professional objectives. A student interested in an interdepartmental program should study the departmental descriptions and review the section on Interdisciplinary Research and Study in Part 1 for opportunities that combine disciplines from MIT’s four other schools with those of the School of Engineering.
While the School’s academic departments and divisions provide continuity and stability for the basic engineering disciplines, they increasingly share interests in the broad areas of application to which their individual disciplines apply. Interdepartmental centers, laboratories, and programs involving the School’s faculty and research staff provide opportunities for faculty and students to undertake collaborative research and engage in educational programs dealing with these and other interdisciplinary applications of importance to society.

Interdisciplinary centers and laboratories that reside in the School of Engineering include the following:

- Center for Technology, Policy, and Industrial Development
- Center for Transportation and Logistics
- Computer Science and Artificial Intelligence Laboratory
- Deshpande Center for Technological Innovation
- Laboratory for Electromagnetic and Electronic Systems
- Laboratory for Information and Decision Systems
- Laboratory for Manufacturing and Productivity
- Materials Processing Center
- Microsystems Technology Laboratories

School of Engineering faculty also participate in the activities of other research centers and laboratories that do not reside in the School of Engineering. For more information on School of Engineering programs, centers, and laboratories, and many others across the Institute, see the section on Interdisciplinary Research and Study in Part 1.

Cross-Departmental Freshman Opportunities
The School of Engineering administers several cross-departmental undergraduate educational opportunities, including Terrascope and Concourse (see the section on Undergraduate Education in Part 1 for more information on these programs).

A new initiative established in 2002, Terrascope is a joint venture of the Schools of Engineering and Science. One of MIT’s learning communities for first-year students, Terrascope uses the study of our Earth system as a context for learning basic science and engineering concepts. Students apply those concepts in creative ways to understand the interdependent physical and biological processes that shape our planet, and to design strategies to ensure a sustainable environment for the future.

Concourse is a collaborative program for freshmen, offered by the Schools of Engineering; Science; and Humanities, Arts, and Social Sciences. The program is composed of many science core classes, as well as a variety of humanities offerings, that not only satisfy most of the General Institute Requirements but also provide students an opportunity to interact closely with faculty and build a solid foundation for studies in any department at MIT. Although Concourse is part of the School of Engineering, its focus is not limited to science or engineering. The Concourse faculty are devoted to integrating science with liberal arts to show the significance of one in the other, to provide a well-balanced academic load, and to expose freshmen to the various departments at MIT. See the section on Undergraduate Education in Part 1 for more information.

School-Wide Electives
The School of Engineering also offers a set of School-Wide Elective (SWE) subjects, each of which is of interest to students from a number of departments in the School. A School-Wide Elective subject may integrate knowledge from several disciplines and illustrate the commonality of the intellectual underpinnings of the departments in the School of Engineering. An SWE subject may be the interface between the academic program of the School of Engineering and programs of other Schools at MIT; be a service subject to engineering students and other students; and be germane to many engineering students without being central to any one departmental program. Please note that registration for these subjects takes place through one of the departmental numbers. For complete subject descriptions and a list of the departmental numbers for each SWE subject, refer to the SWE subject listings at the end of Part 3.

Undergraduate SWE subjects include the following:
- Inventions and Patents
- Management in Engineering
- UPOP IAP Workshop
- UPOP Summer Practice Experience
- UPOP Reflective Learning Experience

Graduate SWE subjects include:
- Application of Technology in Energy and the Environment (H-level graduate credit)
- Engineering Systems Analysis for Design (H-level graduate credit)
- Engineering Risk-Benefit Analysis (H-level graduate credit)
- Innovation Teams

iCampus
Project iCampus, an alliance between MIT and Microsoft Research begun in late 1999, aims to enhance university education through information technology. The goal is to demonstrate leadership in higher education by sponsoring innovative projects with significant, sustainable impact at MIT and elsewhere. iCampus has sponsored over 50 cooperative projects among members of Microsoft Research and students, faculty, and researchers at MIT, particularly in engineering.

iCampus has contributed to a fundamental conceptual overhaul of MIT’s aeronautics and astronautics program that integrates design throughout the entire curriculum; supported a major transformation of MIT’s introduction to computer science that incorporates online lectures and automatic homework checking; and helped replace MIT’s lecture-based Introduction to Mechanical Engineering with small-group engagements, supported by desktop experiments and online study modules. It has also helped to sponsor a radical replacement of MIT’s largest lecture subject, 8.02 Electricity and Magnetism, with an active learning environment where small groups of students use simulation tools and physical laboratory equipment. iCampus is enabling faculty across MIT to create an infrastructure for web-based access to (real) laboratories, where “if you can’t come to the lab, the lab will come to you.” In addition to the projects that MIT faculty have proposed and managed, iCampus has funded over 25 projects run by MIT students, both undergraduate and graduate.
iCampus innovations, demonstrated and validated through use at MIT, aim to impact technical education at both the university and pre-college levels. Possibilities include worldwide sharing of laboratory equipment, replacing passive lectures by active learning experiences, and using speech technology to radically reduce the cost of creating materials for distance education. iCampus has begun to build a global network of affiliate institutions for collaboration in the further development and dissemination of MIT iCampus innovations, with some 60 institutions now ready to participate.

Undergraduate Practice Opportunities Program

The Undergraduate Practice Opportunities Program (UPOP) is sponsored by the School of Engineering and administered through the Office of the Dean of Engineering. Professor Dick K.P. Yue, associate dean of engineering, is the faculty director. Open to all School of Engineering sophomores, this innovative program aims to provide all engineering students the opportunity to appreciate engineering practice outside the academic context through activities emphasizing a combination of knowledge, practice, and reflection. UPOP consists of four parts: an intensive one-week engineering practice workshop offered during IAP; extensive pre-employment workshops taught by MIT alumni during the spring; 10 to 12 weeks of meaningful summer employment; and, in the following fall, assessment interviews with staff members and roundtable meetings with other UPOP students, alumni, and faculty to reflect on the summer experience.

The engineering practice workshop, led by faculty from the School of Engineering and the Sloan School of Management, focuses on the realities of engineering practice and emphasizes fundamental abilities: applying technical skills, communication, teamwork, leadership, and self-awareness. The curriculum has been designed to be highly interactive, involving students in case studies, simulations, and role-play. Students receive three units of academic credit upon successful completion of the course.

The UPOP Summer Practice Experience allows students to gain experience in the entire job cycle, from recruiting to the actual job experience, and is followed by the assessment and reflection process. The UPOP staff helps facilitate the matching of students and employers for 10- to 12-week internships in traditional and start-up companies, nonprofit organizations, and government agencies. Students are required to keep a journal during their internship. Upon completion of the summer practice, both students and employers complete assessments of the summer experience and the program as a whole, and students receive one unit of academic credit.

Students are paid directly by their employer companies for the summer internships. The companies do not pay UPOP any fees, and there are no obligations on either side regarding further employment.

Additional information on the program may be obtained from the Engineering department in which the student is registered or from Christopher Resto, director, Undergraduate Practice Opportunities Program, MIT, Room 12-188, Cambridge, MA 02139, 617-452-5099, fax 617-253-8457; email cresto@mit.edu, or http://web.mit.edu/engineering/upop/.
## Degrees Offered in the School of Engineering

### Aeronautics and Astronautics  Course 16
- **SB** Aerospace Engineering
- **SB** Aerospace Engineering with Information Technology
- **SM** Aeronautics and Astronautics
- **SM/MBA** Engineering/Management—dual degree with Leaders for Manufacturing Program
- **PhD, ScD** Aeronautics and Astronautics
- **PhD, ScD** Aircraft Propulsion
- **PhD, ScD** Astronautics
- **PhD, ScD** Biomedical Engineering
- **PhD, ScD** Computational Fluid Dynamics
- **PhD, ScD** Computer Systems
- **PhD, ScD** Dynamics Energy Conversion
- **PhD, ScD** Estimation and Control
- **PhD, ScD** Flight Transportation
- **PhD, ScD** Fluid Mechanics
- **PhD, ScD** Gas Turbine Structures
- **PhD, ScD** Gas Turbines
- **PhD, ScD** Humans and Automation
- **PhD, ScD** Instrumentation
- **PhD, ScD** Materials Engineering
- **PhD, ScD** Navigation and Control Systems
- **PhD, ScD** Physics of Fluids
- **PhD, ScD** Plasma Physics
- **PhD, ScD** Space Propulsion
- **PhD, ScD** Structural Dynamics
- **PhD, ScD** Structures Technology
- **PhD, ScD** Vehicle Design

### Biological Engineering  Course 20
- **SB** Biological Engineering
- **SM** Toxicology
- **SM/MBA** Engineering/Management—dual degree with Leaders for Manufacturing Program
- **MEng** Biomedical Engineering
- **PhD, ScD** Applied Biosciences
- **PhD, ScD** Bioengineering
- **PhD, ScD** Genetic Toxicology
- **PhD, ScD** Molecular and Systems Bacterial Pathogenesis
- **PhD, ScD** Molecular and Systems Toxicology and Pharmacology
- **PhD, ScD** Molecular Systems Toxicology
- **PhD, ScD** Toxicology

### Chemical Engineering  Course 10
- **SB** Chemical Engineering
- **SB** Chemical-Biological Engineering
- **SM** Chemical Engineering
- **SM** Chemical Engineering Practice
- **SM/MBA** Engineering/Management—dual degree with Leaders for Manufacturing Program
- **PhD, ScD** Chemical Engineering
- **PhD, ScD** Chemical Engineering Practice

### Civil and Environmental Engineering  Course 1
- **SB** Civil Engineering
- **SB** Environmental Engineering Science
- **SM** Civil and Environmental Engineering
- **SM/MBA** Engineering/Management—dual degree with Leaders for Manufacturing Program
- **MEng** Civil and Environmental Engineering
- **PhD, ScD** Biological Oceanography (jointly with WHOI)
- **PhD, ScD** Chemical Oceanography (jointly with WHOI)

### Computation for Design and Optimization
- **SM** Computation for Design and Optimization

### Computational and Systems Biology  Course CSB
- **PhD** Computational and Systems Biology (jointly offered with the School of Science)

### Electrical Engineering and Computer Science  Course 6
- **SB** Computer Science and Engineering
- **SB** Electrical Engineering and Computer Science
- **SB** Electrical Engineering with Information Technology
- **MEng** Electrical Engineering and Computer Science
- **SM** Engineering/Management—dual degree with Leaders for Manufacturing Program
- **Electrical Engineer** in Computer Science
- **PhD, ScD** Computer Science
- **PhD, ScD** Electrical Engineering
- **PhD, ScD** Electrical Engineering and Computer Science

### Engineering Systems  Course ESD
- **SM** Engineering Systems
- **SM** Technology and Policy
- **SM/MBA** Engineering/Management—dual degree with Leaders for Manufacturing Program
- **MEng** Logistics
- **PhD** Engineering Systems
- **PhD** Technology, Management, and Policy

### Materials Science and Engineering  Course 3
- **SB** Archaeology and Materials
- **SB** Materials Science and Engineering
- **SM** Materials Science and Engineering
- **SM/MBA** Engineering/Management—dual degree with Leaders for Manufacturing Program
- **MEng** Materials Science and Engineering
- **PhD, ScD** Bio- and Polymeric Materials
- **PhD, ScD** Biomaterials
- **PhD, ScD** Ceramics
- **PhD, ScD** Electronic Materials
- **PhD, ScD** Electronic, Photonic, and Magnetic Materials
- **PhD, ScD** Emerging, Fundamental, and Computational Studies in Materials Science
- **PhD, ScD** Materials Engineering
- **PhD, ScD** Materials Science
- **PhD, ScD** Polymers
- **PhD, ScD** Structural and Environmental Materials
### Mechanical Engineering  Course 2

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<td>Mechanical Engineering</td>
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<tr>
<td>SM</td>
<td>Mechanical Engineering</td>
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<tr>
<td>SM</td>
<td>Naval Architecture and Marine Engineering</td>
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<tr>
<td>SM</td>
<td>Ocean Engineering</td>
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<td>SM</td>
<td>Oceanographic Engineering (jointly with WHOI)</td>
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<td>SM/MBA</td>
<td>Engineering/Management—dual degree with Leaders for Manufacturing Program</td>
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<tr>
<td>MEng</td>
<td>Manufacturing</td>
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</table>

- Mechanical Engineer
- Naval Engineer
- PhD, ScD Mechanical Engineering
- PhD, ScD Naval Architecture and Marine Engineering
- PhD, ScD Ocean Engineering
- PhD, ScD Oceanographic Engineering (jointly with WHOI)

### Nuclear Science and Engineering  Course 22

<table>
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- Nuclear Engineer
- PhD, ScD Nuclear Science and Engineering

### Ocean Engineering  Course 13

*(For qualifying students registered at MIT by September 2005)*

<table>
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### Polymer Science and Technology

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#### Notes

Many departments make it possible for a graduate student to pursue a simultaneous master’s degree.

Several departments also offer undesignated degrees, which lead to the Bachelor of Science without departmental designation. The curricula for these programs offer students opportunities to pursue broader programs of study than can be accommodated within a four-year departmental program.

1. See Interdisciplinary Graduate Programs section in Part 2.
The mission of the Department of Aeronautics and Astronautics is to prepare engineers for success and leadership in the conception, design, implementation, and operation of aerospace and related engineering systems. This is achieved through a commitment to educational excellence; to the creation, development, and application of the technologies critical to aerospace vehicle and information engineering; and to the architecture and engineering of complex high-performance systems.

Graduates with an aerospace engineering degree will find career opportunities in commercial and military aircraft and spacecraft engineering, space exploration, the air transportation and space-based telecommunication industries, teaching, research, military service, and many related technology-intensive fields such as transportation, information, and the environment. A demanding technical education with a strong emphasis on understanding complex systems has also proved to be excellent preparation for careers in business, law, medicine, and public service.

Aerospace engineering centers on the design of extremely sophisticated machines ranging from vertical take-off aircraft and jet transports to rockets and spacecraft. Internal to these vehicles are modern software, information, and navigation systems. The vehicles themselves are part of larger transportation and communication systems. Critical disciplines and technologies in this field include the mechanics and physics of fluids; structures and materials; propulsion and energy conversion; information, communication, control, and estimation; humans, automation, and autonomy; and avionics. An increasingly important feature of the field is the ability to architect and engineer the complex engineering systems built upon these disciplines and technologies. Central objectives of the educational program are to teach students how to learn, how to use basic principles to solve engineering problems, and how to foresee the consequences of their solutions and designs. A faculty of approximately 35 men and women teaches and interacts with students at all degree levels.

During the 1990s, the department undertook a comprehensive review of its degree programs in light of the rapid global changes in technology and society. The academic programs based in engineering science have been revised to be technically rigorous while set in the context of modern engineering: the conception, design, implementation and operation (CDIO) of products and systems which must provide performance in an economically competitive and environmentally acceptable way. These requirements, and a new emphasis on understanding how individuals learn, have resulted in a reshaping of the department’s degree programs and teaching methods.

The Bachelor of Science (SB) degree is a four-year program designed to prepare the graduate for an entry level position in the aerospace field and for further education at the master’s level. Two degrees are available, one that emphasizes the disciplines that relate to the engineering of aerospace vehicles and a second that defines a specialization in aerospace information technology. Both degrees retain a deep emphasis on the fundamentals and provide strong integration with the overarching CDIO context. The program includes an opportunity for a year abroad. See the section Undergraduate Study for further details.

The Master of Science (SM) degree is a one- to two-year program of graduate study with a beginning research or design experience represented by the SM thesis.

The department is an active participant and sponsor of the System Design and Management Program (SDM), which leads to a Master of Science in Engineering and Management. This is a program for professional engineers who seek to build upon their technical backgrounds to become a new breed of technical leaders, with the blend of engineering and management skills required to conceive and create today’s increasingly complex products and systems.

Finally, the department offers the doctoral degree, which emphasizes in-depth study with a significant research project in a focused area. Students are admitted to the doctoral program upon passing the qualifying examination. The doctoral degree is awarded after completion of an individual course of study, passing the general examinations, and submission and defense of a thesis embodying an original research contribution.

The faculty and students are engaged in approximately 200 research projects organized into 10 departmental laboratories and centers, including the Aerospace Computational Design Laboratory, Aerospace Controls Laboratory, Complex Systems Laboratory, Gas Turbine Laboratory, Humans and Automation Lab, International Center for Air Transportation, Lean Aerospace Initiative, Man Vehicle Laboratory, Space Systems Laboratory, Technology Laboratory for Advanced Materials and Structures, and Wright Brothers Wind Tunnel. See the Research Laboratories and Activities section below for information on specific research agenda. Many of the department’s research projects are open to undergraduates through the Undergraduate Research Opportunities Program. In addition, research activities in other MIT laboratories and centers are open to students registered in Aeronautics and Astronautics.

The department recently constructed a Learning Laboratory for Complex Systems, focused on our Conceive-Design-Implement-Operate strategy for complex high-performance engineering systems and products. This Learning Laboratory provides enhanced opportunities for hands-on learning experiences that are closely integrated to the department’s educational curriculum.

There are several new facilities in the Learning Laboratory dedicated for student use. The Arthur Gelb Laboratory features a modern machine shop, a composites fabrication facility, an electronics design lab, and a large team projects area with worktables and equipment for student projects. The Robert C. Seamans Jr. Laboratory is a community study area with meeting and discussion rooms, a design/conference room equipped for sophisticated videoconferencing, IT, and audio-visual systems, and a comprehensive aerospace library. The Design Studio provides computers and telecommunications resources to facilitate concurrent engineering sessions and televised distance learning. The Gerhard Neumann Hangar includes student-operated low-speed and supersonic wind tunnels, an array of computers equipped with flight simulation software, engineering hardware displays, and workspace for large-scale student projects.

Sectors of Instruction

The department’s faculty is organized into three sectors of instruction. Typically, a faculty member teaches both undergraduate and graduate subjects in one or more of the sectors. The following descriptions of each sector introduce the undergraduate and graduate degree programs.
outlined in subsequent sections. Refer to Part 3 for specific subject descriptions.

**Information Sector**
A majority of the aerospace systems of the future will either center on or critically depend upon information technology, and all will exploit information technology to an increasing extent. The missions of many aerospace systems are fundamentally centered on gathering, processing, and transmitting information. Examples where information technology is central include communication satellites, surveillance and reconnaissance aircraft and satellites, planetary rovers, global positioning satellites, the air transportation system, and integrated defense systems. Other aerospace systems also must rely on information technology-intensive sub-systems to provide important onboard functions, including fly-by-wire flight control, autonomous or semi-autonomous guidance and control, cooperative action including flight in formations or swarms, and health monitoring systems. Furthermore, almost every aircraft or satellite is one system within a larger system. Information plays a central role in the interoperability of systems within a system-of-systems. Recognizing the dominant and growing role information plays in aerospace, the Department of Aeronautics and Astronautics formed the Information Sector in the fall of 2004, integrating faculty members from the previous Information and Control and Humans and Automation divisions.

Faculty members in the Information Sector teach and perform research on a broad range of areas including the disciplines of guidance, navigation, control, autonomy, communication, networks, and real-time mission-critical software and hardware. In many instances, the functions provided by aerospace information systems are critical to life or mission success. The complex nature of an aerospace system can either be simplified by the use of information technologies or can become significantly more complicated through the misuse of information technologies. Hence, safety, fault-tolerance, verification, and validation are significant areas of inquiry. Ongoing research in this sector includes command and control of multiple unmanned/autonomous vehicles, space and airborne communication systems and networks, and software development methods for flight and mission-critical systems, investigation of air traffic management, and application of control to smart systems.

The Information Sector has strong linkages to the department’s Aerospace Systems Sector, particularly with issues related to how humans interact with aerospace vehicles. Other common interests include the safety aspects of large, mission-critical software systems, the design and operation of air transportation systems, and the design and operation of satellite systems. The sector also has linkages to the Vehicles Technology Sector. Current interests include research on unmanned aerial vehicles and smart structures. Moreover, the sector maintains linkages to the Electrical Engineering and Computer Science Department and the Engineering Systems Division through joint teaching and collaborative research in communication, networks, control, robotic systems, optimization, numerical techniques, and algorithms.

**Aerospace Systems Sector**
This sector is responsible for instruction and research in systems engineering, a discipline that denotes the methodologies used in the architecting, design, manufacture, and operation of the highly complex and demanding systems in the field of aeronautics and astronautics. The sector consists of faculty members with research specialties in this area, as well as faculty affiliates representing the full disciplinary strength of the department.

The systems approach considers all factors important to the performance, economic viability, manufacture, acceptability, and operation of engineering systems—technical, social, environmental, production, financial, and safety aspects—and attempts to find optimal or best-value tradeoffs among them while considering risk and uncertainty. The systems engineer must deal simultaneously with these factors, whether the objective is the transport of passengers in commercial aircraft, orbital communications, or the exploration of space, among others.

This sector addresses issues related to how humans interact with aerospace vehicles, including information-related and life-support aspects. Safety, fault-tolerance, verification, and validation are significant areas of inquiry. Ongoing research in the sector includes investigation of air traffic management, distributed satellite systems, enterprise architecture, integrated design of space-based optical systems, micro-gravity research into human physiology and technology maturation, and software development methods for flight and mission-critical systems.

Students interested in systems engineering should develop a strong background in some of the disciplines that support systems analysis, such as probability, statistics, optimization, operations research, manufacturing, and economics. Research labs associated with the activities of this sector include the Man Vehicle Laboratory, Space Systems Laboratory, Lean Aerospace Initiative, International Center in Air Transportation, Operations Research Center, and Complex Systems Research Laboratory. Many of the department faculty in this sector are also associated with the Engineering Systems Division.

**Vehicle Technologies Sector**
The faculty in this sector is responsible for teaching and research in the fields of fluid mechanics, propulsion, materials, and structures—technologies needed for the design of aerospace vehicles. Although these can be considered disciplinary fields, the faculty emphasizes interdisciplinary approaches in its teaching and research.

The intellectual breadth of the sector is wide, with a span of activities reaching from fundamental engineering science to design techniques, to measurement technology, to the detailed engineering of complex vehicle components and systems. Topics of interest include the computational design of fluid, material, and structural systems; heat transfer, aerodynamics, and fluid dynamics; reduced order modeling of unsteady fluid flows and structures in aerospace devices; structural dynamic analysis and control; turbomachinery; robust design of propulsion and energy system components; electric and chemical space propulsion; gas turbine engine design; propulsion system integration; aerospace noise, emissions, and environmental impact; microelectromechanical systems; multi-scale modeling and simulation of advanced materials: engineered materials, failure mechanisms, and structural life monitoring; and biofluid mechanics.

The sector includes several large interdisciplinary projects, including the Silent Aircraft Initiative and the MIT Micro Engine Project.
Research laboratories affiliated with the sector include the Aerospace Computational Design Laboratory, FAA/NASA Center of Excellence: Partnership for Air Transportation Noise and Emissions Reduction, the Gas Turbine Laboratory, the Space Propulsion Laboratory, and the Technology Laboratory for Advanced Materials and Structures.

UNDERGRADUATE STUDY

Bachelor of Science in Aerospace Engineering/Course 16-1 or Aerospace Engineering with Information Technology/Course 16-2

Undergraduate study in the department leads to either the Bachelor of Science in Aerospace Engineering (Course 16-1) or the Bachelor of Science in Aerospace Engineering with Information Technology (Course 16-2) at the end of four years.

The undergraduate curriculum provides a foundation for the student to become a practicing engineer upon receipt of either undergraduate degree, to continue on to graduate studies in any of the specialties, or to continue in other fields as well.

The curriculum includes the General Institute Requirements described in the section on Undergraduate Education in Part 1 and the departmental program. The departmental program includes a fall-spring-fall sequence of subjects called Unified Engineering, Dynamics, and Principles of Automatic Control; a probability systems analysis subject and a subject in computers and engineering problem solving; professional area subjects; an experimental projects laboratory; and a capstone design subject. The program also includes the subject Differential Equations.

The department has initiated a major effort aimed at making the conception-design-implementation-operation (CDIO) of aerospace and related complex high performance systems and products the engineering context of its education. The skills and attributes emphasized in the educational program go beyond the formal classroom curriculum and include: modeling, design, the ability for self education, computer literacy, communication and teamwork skills, ethical context, and underlying all of these, appreciation for and understanding of interfaces.
and connectivity between various disciplines. Opportunities for formal and practical (hands-on) training in these areas are integrated into the departmental subjects through examples set by the faculty, subject content, and the ability for substantive engagement in the CDIO process in the department’s Learning Laboratory for Complex Systems.

Unified Engineering is offered in sets of two 12-unit subjects in two successive terms. These subjects are taught cooperatively by several faculty members. Their purpose is to introduce new students to the disciplines and methodologies of aerospace engineering at a basic level, with a balanced exposure to analysis, empirical methods, and design. The areas covered include statics, materials and structures; thermodynamics and propulsion; fluid mechanics; and signals and systems. Several laboratory experiments are performed and a number of systems problems tying the disciplines together are included.

Unified Engineering is usually taken in the sophomore year and Dynamics and Principles of Automatic Control in the first term of the junior year. Introduction to Computers and Engineering Problem Solving can be taken at any time, starting in the freshman year, but the fall term of the sophomore year is recommended.

The professional area subjects treat more completely and in greater depth the material to which the student is introduced in the core. In both degree programs, students take four subjects (48 units) from among the professional area subjects, with subjects in at least three areas. In Course 16-1, students must take at least two subjects designated as Aerospace Engineering. In Course 16-2, the student must take at least three subjects from among the Aerospace Information Technology list.

The subjects listed as Aerospace Engineering represent the more traditional aerospace disciplines encompassing the design and construction of airframes and engines. This includes fluid mechanics, aerodynamics, heat and mass transfer, computational mechanics, flight vehicle aerodynamics, solid mechanics, structural design and analysis, the study of engineering materials, structural dynamics, and propulsion and energy conversion from both fluid/thermal (gas turbines and rockets) and electrical devices.

The subjects listed as Aerospace Information Technology are in the broad disciplinary area of information, which plays an ever increasing role in modern aircraft and spacecraft. This includes feedback, control, estimation, control of flight vehicles, software engineering, human factors engineering, aerospace communications and digital systems, the way in which humans interact with the vehicle, through manual control and supervisory control of telerobotic processes (e.g., modern cockpit systems and human centered automation) and how planning and real time decisions are made by machines.

Subjects in aerospace information technology are taught in both the Departments of Aeronautics and Astronautics and Electrical Engineering and Computer Science.

The capstone subjects serve to integrate the various disciplines and emphasize the Conceive-Design-Implement-Operate context of our curriculum. They also satisfy the Institute requirement as Communication-Intensive (CI-M) subjects. The vehicle and system design subjects (16.82 and 16.83) require student teams to apply their undergraduate knowledge to the design of an aircraft or spacecraft system. One of these two subjects is required and is typically taken in the second term of the junior year or in the senior year. The rest of the capstone requirement is met by one of three 18-unit subject sequences: 16.621 and 16.622 Experimental Projects I and II; or 16.821 Flight Vehicle Development; or 16.831 and 16.832 Space Systems Development I and II. These sequences satisfy the Institute laboratory requirement. In 16.821 and 16.831/16.832 students build and operate the vehicles or systems developed in 16.82 and 16.83. In 16.621/16.622, students conceive, design, and execute an original experimental research project in collaboration with a partner and a faculty advisor.

To take full advantage of the General Institute Requirements and required electives, the department recommends the following: 3.091 for the chemistry requirement; the ecology option of the biology requirement; a subject in economics (e.g., 14.01) as part of the HASS Requirement; and elective subjects such as 16.00 Introduction to Aerospace and Design, a mathematics subject (e.g., 18.06, 18.075, or 18.085), and additional professional area subjects in the departmental...
program. Other elective options include the following six-unit subjects: 16.810 Design and Rapid Prototyping, offered during the Independent Activities Period, and 16.812 The Aerospace Industry, offered in the spring term.

Double Degree Program
Students may pursue two SB degrees under the Double Degree Program outlined in the section on Undergraduate Education in Part 1. In particular, some students may wish to combine a professional education in aeronautics and astronautics with a liberal education that links the development and practice of science and engineering to their social, economic, historical, and cultural contexts. For them, the Department of Aeronautics and Astronautics and the Program in Science, Technology, and Society offer a double degree program that combines majors in both fields. For a detailed description of that integrated degree program, refer to the description of the Program in Science, Technology, and Society in Part 2.

Undergraduate Opportunities
The following programs exist to broaden the opportunities available to undergraduate students.

Undergraduate Research Opportunities Program
To take full advantage of the unique research environment of MIT, undergraduates are encouraged to become involved in the research activities of the department through the Undergraduate Research Opportunities Program (UROP). Many of the faculty actively seek undergraduates to become a part of their research teams. Specific areas of research opportunity are outlined in the section Research Laboratories and Activities below. For more information, please contact Marie Stuppard in the Aero/Astro Academic Programs Office, Room 33-208, 617-253-2279, mas@mit.edu.

Undergraduate Practice Opportunities Program
The Undergraduate Practice Opportunities Program (UPOP) is a program sponsored by the School of Engineering and administered through the Office of the Dean of Engineering. Open to all School of Engineering sophomores, this program provides students an opportunity to develop engineering and business skills while working in industry, non-profit organizations, or government agencies. UPOP consists of three parts: an intensive one week engineering practice workshop offered during IAP, 10-12 weeks of summer employment, and a written report and oral presentation in the fall. Students are paid during their periods of residence at the participating companies and also receive academic credit in the program. There are no obligations on either side regarding further employment. For more information, please contact Barbara Lechner in the Aero/Astro Academic Programs Office, Room 33-208, 617-258-7243, blechner@mit.edu.

Summer Internship Program
The Summer Internship Program provides undergraduates in the Department of Aeronautics and Astronautics the opportunity to apply the skills they are learning in the classroom in paid professional positions with employers throughout the United States. Students are offered individual career advising as well as seminars on resume writing, interviewing, and the job search process. Some students also choose to receive academic credit for their work experience by participating in a three-part educational process including preparation activity, the work experience, and reflection/evaluation activities when they return to school in the fall. For more information, please contact Barbara Lechner in the Aero/Astro Academic Programs Office, Room 33-208, 617-258-7243, blechner@mit.edu.

Year Abroad Program
The department offers its undergraduate students an optional Year Abroad Program in partnership with several foreign schools of aeronautics and astronautics. Current partner schools are: Imperial College (London), École Nationale Supérieure de L’Aéronautique et de L’Espace (ENSEA, Toulouse, France), Escuela Técnica Superior de Ingenieros Aeronáuticos (ETSIA, Madrid, Spain), Royal Technical Institute of Sweden (KTH, Stockholm), University of Stuttgart (Germany), and the Swiss Federal Institute of Technology (ETH, Zurich). The department is also participating in the Cambridge University-MIT (CME) undergraduate exchange program. Students participate in the academic cycle of the host institution and take courses in the local language. Students plan their course of study in advance; this includes securing credit commitments in exchange for satisfactory performance abroad. A grade average of B or better is normally required of participating MIT students. For more information, contact Professor Manuel Martínez-Sánchez, Room 37-341, 617-253-5613. Also refer to Undergraduate Education in Part 1 for detailed information on the CME program.

Massachusetts Space Grant Consortium
MIT leads the NASA-supported Massachusetts Space Grant Consortium, collaborating with Harvard University, Wellesley College, Tufts University, Boston University, University of Massachusetts, Worcester Polytechnic Institute, the Marine Biological Laboratory, Five College Astronomy Department, the Boston Museum of Science, Northeastern University/Center for Advanced Microgravity, Materials Processing (CAMMP), the Christa McAuliffe Center/Framingham College, College of the Holy Cross, Williams College, Olin College of Engineering, and many aerospace companies and laboratories throughout the US. The program has the principal objective of stimulating and supporting student interest, especially that of women and underrepresented minorities, in space engineering and science at all educational levels, primary through graduate. The program offers a number of activities to this end, including sponsorship of undergraduate research projects, a spring undergraduate seminar on Modern Space Science and Engineering, an annual public lecture by a distinguished member of the aerospace community, summer workshops for precollege teachers, and fellowships for first-year graduate study. An important function of the program is coordinating placement of students in summer positions in industry, and nomination to the NASA summer academies. For more information, contact the program coordinator, Massachusetts Space Grant Consortium, Room 33-208, Cambridge, MA 02139-4307, 617-258-5546, masgc@mit.edu.

Inquiries
For additional information concerning academic and research programs in the department, suggested four-year undergraduate programs, and interdisciplinary programs, please contact the Department of Aeronautics and Astronautics Academic Programs Office, Room 33-208, MIT, 617-253-2279, mas@mit.edu.
GRADUATE STUDY

Graduate study in the Department of Aeronautics and Astronautics includes graduate-level subjects in Course 16 and other Courses at MIT, and research work culminating in a thesis. Degrees are awarded at the master’s, engineer’s, and doctoral levels. The range of subject matter is described in the section Sectors of Instruction; subjects are listed in Part 3. The section Research Laboratories and Activities provides an overview of research interests. Detailed information may be obtained from the Department Academic Programs Office or from individual faculty members.

Entrance Requirements

In addition to the general requirements for admission to the Graduate School, applicants to the Department of Aeronautics and Astronautics should have a strong undergraduate background in the fundamentals of aerospace engineering and mathematics as described in the section Undergraduate Study. In some cases, unfulfilled entrance requirements may also be satisfied during the first year of admission to the graduate program.

International students whose language of instruction has not been English in their primary and secondary schooling must pass the Test of English as a Foreign Language (TOEFL) with a minimum score of 250/600 to be considered for admission to this department. TOEFL waivers are not accepted. No other exam fulfills this requirement.

All applicants to the graduate program in Aeronautics and Astronautics must submit the Graduate Record Examination (GRE) test results.

New graduate students are normally admitted as candidates for the degree of Master of Science. Since requirements for candidates for the Engineer in Aeronautics and Astronautics are more rigorous, admission is ordinarily considered only after the candidate has spent some time in residence at MIT.

Admission to the doctoral program is offered to students who have been accepted for graduate study and have passed the Doctoral Qualifying Examination. The qualifying examination seeks to measure the candidate’s aptitude for engineering research and understanding of the fundamental principles underlying aerospace engineering. This examination is offered once each year, during the January Independent Activities Period. Students who wish to be considered for the doctoral program must take the qualifying examination before the fourth term following initial registration in the graduate program.

The Department of Aeronautics and Astronautics requires that all entering graduate students demonstrate satisfactory English writing ability by taking the Technical Writing Diagnostic Examination offered by the Program in Writing and Humanistic Studies. The examination is usually administered during the week after the initial date of registration in graduate school, and all entering candidates must take the examination at that time. Students with deficient skills must complete remedial training specifically designed to fulfill their individual needs. The remedial training prescribed by the Writing Program must be completed by the end of the first Independent Activities Period following initial registration in the graduate program.

All incoming graduate students whose native language is not English are required to take the Department of Humanities English Evaluation Test (EET) offered at the start of each regular term. This test is a proficiency examination designed to indicate areas where deficiencies may still exist and recommend specific language subjects available at MIT.

All graduate programs in the department require one or two graduate-level mathematics subjects. The requirement is satisfied only by graduate-level subjects on the list approved by the department graduate committee. For students with a strong mathematical background, the requirement may be satisfied by taking one subject from the list of advanced math subjects approved by the graduate committee and achieving a grade of B or better. The specific choice of math subjects is arranged individually by each student in consultation with their faculty advisor.

All entering students will be provided with additional information concerning the requirements for all of the graduate degree programs in the department, including lists of recommended subjects.

Master of Science in Aeronautics and Astronautics

The general requirements for the Master of Science degree are cited in the section on General Degree Requirements for graduate students in Part 1. The specific departmental requirements include at least 66 subject units, typically in graduate subjects relevant to the candidate’s area of technical interest. Of the 66 units, 42 units must be in H-level subjects, of which at least 21 units must be in departmental subjects. To be credited toward the degree, graduate subjects that are not H-level must carry a grade of B or better. In addition, a 24-unit thesis is required beyond the 66 units of coursework. Full-time students normally must be in residence one full academic year. Special students admitted to the SM program in this department must enroll in and satisfactorily complete at least two graduate H-level subjects while in residence (i.e., after being admitted as a degree candidate) regardless of the number of subjects which have been completed before admission to the program. Students holding research assistantships typically require a longer period of residence.

Engineer in Aeronautics and Astronautics

The program leading to the degree of Engineer in Aeronautics and Astronautics is offered for students interested in a greater breadth of graduate subjects than is normally associated with a master’s or doctoral program, and less emphasis on research than required of doctoral candidates. The minimum study program of 162 subject units must include graduate subjects from each of the sectors, and the thesis work must have a strong engineering, as distinct from a scientific, orientation. Two years beyond the Bachelor of Science degree normally are the minimum required for completion of this degree by a full-time student.

Doctor of Philosophy and Doctor of Science

The general requirements for this degree are given in the section on General Degree Requirements for graduate education in Part 1. To be considered for the doctoral program in the department, a candidate must pass the Doctoral Qualifying Examination. Other requirements for admission to the program and for the program
itself are outlined in a booklet entitled The Doctoral Program. Students planning on a doctoral program should download a copy of this booklet from the website as soon as they enter the department. After selecting an area for study and research, the doctoral candidate, in consultation with the thesis supervisor, forms a doctoral thesis committee, which assists in the formulation of the individual’s research and study programs and monitors the student’s progress. The subjects selected to fulfill the major and minor program requirements must be approved by this committee. Mastery of the major area is tested by a written and an oral General Examination administered by the doctoral thesis committee after completion of the major area subjects. Demonstrated competence for original research at the forefront of aerospace engineering is the final and major criterion for granting the doctoral degree. The candidate’s thesis serves in part to demonstrate such competence, and on completion is defended orally in a presentation to the faculty of the department, who may then recommend the degree be awarded.

Interdisciplinary Programs
The department participates in several interdisciplinary fields at the graduate level, which are of special importance for aeronautics and astronautics in both research and the curriculum.

Biomedical Engineering
This program is available to students interested in biomedical instrumentation and physiological control systems where the disciplines involved in aeronautics and astronautics are applied to biology and medicine. Graduate study combining aerospace engineering with biomedical engineering may be pursued by departmental students in conjunction with the Harvard-MIT Division of Health Sciences and Technology (HST) SM-PhD Program in Medical Engineering and Medical Physics, or the PhD and MEng programs in the Biological Engineering Division (BE). Students wishing to pursue a degree through HST or BE must also apply to those graduate programs. At the master’s degree level, students in the department may specialize in biomedical engineering research, emphasizing space life sciences and life support, instrumentation and control, or in human factors engineering and in instrumentation and statistics. For further descriptions of these programs, please see the listing for the Center for Biomedical Engineering in the section on Interdisciplinary Research and Study in Part 1. Most biomedical engineering research in the Department of Aeronautics and Astronautics is conducted in the Man Vehicle Laboratory.

Computation for Design and Optimization
The Computation for Design and Optimization (CDO) master’s degree program is available to graduate students interested in the analysis and application of computational approaches to designing and operating engineered systems. The curriculum is designed with a common core that serves all engineering disciplines, and an elective component that focuses on particular applications. Current MIT graduate students can pursue a CDO master’s degree in conjunction with their departmental master’s or doctoral studies. For further information, see the program description in the Interdisciplinary Graduate Programs section in Part 2 or visit http://web.mit.edu/cdo-program/.

Flight Transportation
For students interested in a career in flight transportation, a program is available that incorporates a broader graduate education in disciplines such as economics, management, law, and operations research than is normally pursued by candidates for degrees in engineering. Graduate research emphasizes one of the four areas of flight transportation: Airport Planning and Design; Air Traffic Control; Air Transportation Systems Analysis; and Airline Economics and Management, with subjects selected appropriately from those available in the Departments of Aeronautics and Astronautics, Civil and Environmental Engineering, Economics, and the Center for Transportation Studies. A special interdepartmental program may be established for the doctoral student, or participation in the Operations Research Center Program may be considered—see the section on Graduate Programs in Operations Research in Part 2.

Leaders for Manufacturing
The Leaders for Manufacturing (LFM) program combines graduate education in engineering and management for those with two or more years of work experience who aspire to leadership positions in manufacturing or operations companies. This rigorous 24-month program combines subjects in technology and management. A required 6.5-month internship provides opportunity to complete a research project on site at one of LFM’s partner companies. The internship leads to a dual-degree thesis, culminating in two master’s degrees—an SM in management or an MBA, and an SM in engineering from the Department of Aeronautics and Astronautics. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description in the Engineering Systems Division section in Part 2 or visit http://lfm.mit.edu/.

System Design and Management
The System Design and Management (SDM) program is a partnership among industry, government, and the university for educating technically grounded leaders of 21st-century enterprises. Jointly sponsored by the School of Engineering and the Sloan School of Management, it is MIT’s first degree program to be offered with a distance learning option in addition to a full-time in-residence option. For more information, see the program description in the Engineering Systems Division section in Part 2, or visit http://sdm.mit.edu/.

Technology and Policy
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 TPP 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 in the Engineering Systems Division section in Part 2, or visit http://tppserver.mit.edu/.
Fellowships, Research and Teaching Assistantships

Financial assistance for graduate study may be in the form of fellowships or research or teaching assistantships. Both fellowship students and research assistants work with a faculty supervisor on a specific research assignment of interest, which generally leads to a thesis. Teaching assistants are appointed to work on specific subjects of instruction.

A special relationship exists between the department and the Charles Stark Draper Laboratory. This relationship affords fellowship opportunities for SM and PhD candidates who perform their research as an integral part of ongoing projects at the Draper Laboratory. Faculty from the department maintain close working relationships with researchers at Draper, and thesis research at Draper performed by Draper Fellows can be structured to fulfill MIT residency requirements. Further information on the Draper Laboratory can be found in the section on Interdisciplinary Research and Study in Part 1.

Inquiries

For additional information concerning academic, research, and interdisciplinary programs in the department, please contact Marie Stuppard, mas@mit.edu. For information concerning admissions, financial aid and assistantships, please contact Barbara Lechner, blechner@mit.edu, or Beth Marois, bethamar@mit.edu.

Research Laboratories and Activities

The department’s faculty, staff and students are engaged in a wide variety of research projects. Graduate students participate in all the research projects. Projects are also open to undergraduates through the Undergraduate Research Opportunities Program (UROP). Some projects are carried out in an unstructured environment by individual professors working with a few students. Most projects are found within the departmental laboratories and centers listed below. Faculty also undertake research in the Computer Science and Artificial Intelligence Laboratory, Draper Laboratory, Laboratory for Information and Decision Systems, Lincoln Laboratory, Operations Research Center, Research Laboratory of Electronics, and the Program in Science, Technology, and Society, as well as in interdepartmental laboratories and centers listed in the introduction to the School of Engineering. Refer to the section on Interdisciplinary Research and Study in Part 1 for more detailed descriptions.

Aerospace Computational Design Laboratory

The mission of the Aerospace Computational Design Laboratory (ACDL) is to improve the design of aerospace systems through the advancement of computational methods and tools which incorporate multidisciplinary analysis and optimization, probabilistic and robust design techniques, and next-generation computational fluid dynamics. The laboratory studies a broad range of topics which focus on the design of aircraft and aircraft engines.

Aerospace Controls Laboratory

The Aerospace Controls Laboratory (ACL) is involved in research topics related to control design and synthesis for aircraft and spacecraft. Theoretical research is pursued in areas such as high-level decision making, path planning, task assignment, estimation, navigation using Global Positioning Systems, robust control, optimal control, and model predictive control. Experimental and applied research is also a major part of ACL. The advanced unmanned aerial vehicle, rover, automobile, and satellite testbeds enable students to implement their algorithms in actual hardware and evaluate the proposed techniques. Recent research has expanded into quad-rotor helicopters.

Complex Systems Research Lab

Increasing complexity and coupling as well as the introduction of new digital technology are introducing new challenges for engineering, operations, and sustainment. We are designing system modeling, analysis, and visualization theory and tools to assist in the design and operation of safer systems with greater capability. To accomplish these goals, we apply a system’s approach to engineering that includes building technical foundations and knowledge and integrating these with the organizational, political and cultural aspects of system construction and operation.

While our main emphasis is aerospace systems and applications, our research results are applicable to complex systems in such domains as transportation, energy, and health. Current research projects include accident modeling and design for safety; model-based system and software engineering; reusable, component-based system architectures; interactive visualization; human-centered system design; system diagnosis and fault tolerance; system sustainment; and organizational factors in engineering and project management.

Gas Turbine Laboratory

Work in the laboratory is focused on advanced propulsion systems and turbomachinery. Activities include computational, theoretical, and experimental study of transonic turbomachines; stability of compression systems; heat transfer in turbine blading; engine noise reduction; performance enhancement of propulsion devices through embedded streamwise vorticity for both reacting and non-reacting flows; and vortical structure and unsteady flows in turbomachines. The laboratory also provides a focus for research directed at quantifying and reducing the environmental impact of aerospace systems. Major research thrusts are pollutant emissions and community noise, two areas of significant concern for current and future aircraft. Two other major research areas are work on “smart engines,” in which active control is utilized to enhance the dynamic performance of propulsion system components, and “micro engines,” i.e., gas turbine engines of millimeter diameter with blading fabricated using microfabrication techniques.

Humans and Automation Laboratory

The Humans and Automation Laboratory (HAL) focuses on the multifaceted interactions of human and computer decision making in complex sociotechnical systems.

With the explosion of automated technology, the need for humans as supervisors of complex automatic control systems has replaced the need for humans in direct manual control. A consequence of complex, highly automated domains in which the human decision maker is more “on-the-loop” than “in-the-loop” is that the level of required cognition has moved from that of well-rehearsed skill execution and
rule following to higher, more abstract levels of knowledge synthesis, judgment, and reasoning.

Employing human-centered design principles to human supervisory control problems, and identifying ways in which humans and computers can leverage the strengths of the other to achieve superior decisions together is the central focus of HAL. Current research projects include collaborative human-computer decision making for command and control domains, investigating human understanding of multivariable optimization algorithms and visualization of cost (objective functions); the need for bounded collaboration, design of Lunar Lander displays, human supervisory control of multiple heterogeneous unmanned vehicles; collaborative time-sensitive targeting; and developing metrics for evaluating display complexity.

International Center for Air Transportation
The mission of ICAT is to contribute to improving the safety and effectiveness of air transportation worldwide by education and the use of information technologies. Current areas of research interest include: advanced Air Traffic Control and Management (ATM, ATC) systems; satellite-based Communication, Navigation, and Surveillance (CNS) systems in mature and developing world regions; advanced flight information systems; airline management; and operations (both flight operations and operations research). ICAT works closely with the Engineering Systems Division, the Center for Transportation Studies, and the Operations Research Center.

Lean Aerospace Initiative
The Lean Aerospace Initiative (LAI) is a research partnership among industry, government, and academia with a mission to research, develop and promulgate the knowledge, principles, practices, and tools to enable and accelerate the envisioned transformation of the US aerospace enterprise through people and processes. Though it resides in the Center for Technology, Policy and Industrial Development (CTPID) in the School of Engineering, Department of Aeronautics and Astronautics faculty play a lead role in it. LAI undertakes research in all areas related to improving enterprise processes for acquiring, designing, developing, producing, and supporting aircraft, spacecraft, engines, and missiles.

For more information about LAI, see Part 1: Interdisciplinary Research and Study.

Man Vehicle Laboratory
The laboratory’s goal is to optimize human-vehicle system effectiveness by improving our understanding of human physiological and cognitive capabilities with particular emphasis on human spaceflight. Research is interdisciplinary, utilizing techniques from manual and supervisory control, estimation, signal processing, robotics, biomechanics, cognitive psychology, artificial intelligence, sensory-motor physiology, human factors, and biostatistics. The laboratory has several experiments in development for the International Space Station, and other ground-based projects sponsored by NASA and the National Space Biomedical Institute. Research focuses on control of posture and locomotion in partial gravity, spatial orientation in both real and virtual environments, aircraft cockpit displays and controls, and physiological and human factors aspects of EVA and artificial gravity systems, and design of exploration class missions.

Space Systems Laboratory
The Space Systems Laboratory’s (SSL) mission is to develop the technology and systems analysis associated with small spacecraft, precision optical systems, and International Space Station technology research and development. The laboratory encompasses expertise in structural dynamics, control, thermal, space power, propulsion, software development, and systems. Major activities include the development of small spacecraft thruster systems and the examination of issues associated with the distribution of function among satellites. In addition, technology is being developed for spacelift validation in support of a new class of space-based telescope which exploits the physics of interferometry to achieve dramatic breakthroughs in angular resolution. The objective of the laboratory is to explore innovative concepts for the integration of future space systems and to train a generation of researchers and engineers conversant in this field.

Technology Laboratory for Advanced Materials and Structures
The Technology Laboratory for Advanced Materials and Structures (TELAMS), formerly known as TELAC, has provided leadership in advancing the knowledge and capabilities of the composites and structures community through education of students, original research, and interaction with the community at large. The laboratory’s emphasis on composite materials has led to research topics ranging from a basic understanding of composite materials to their behavior in specific structural configurations, with the ultimate objective of gaining a sufficient understanding of their properties and how those properties interact to determine the behavior of laminates and structures made of composite materials. Recently, the focus of the laboratory has broadened into other areas, including multi-scale modeling and simulation of the mechanics of advanced materials used in the aerospace industry, with emphasis on understanding the influence of microstructural features of deformation and failure in their effective engineering response; and design, fabrication, and testing of microelectromechanical systems together with their associated materials and processes.

Wright Brothers Wind Tunnel
The largest on the MIT campus, this wind tunnel has a 7x10-foot cross-section, and is capable of steady flow speeds up to 200 mph. The facility is used for graduate and undergraduate instruction and research, as well as testing for outside companies. Active research and educational programs include aerodynamics of airplanes and space vehicles and the simulation of wind loads on architectural structures. Recently, the tunnel has been involved in aerodynamic test programs for Olympic athletes and sporting equipment such as bicycles and skis.
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The mission of the Biological Engineering Division (BE) is to educate leaders and generate and communicate new knowledge integrating engineering with biology. Combining quantitative, physical, and integrative principles with advances in mechanistic molecular and cellular bioscience, biological engineering increases understanding of how biological systems function as both physical and chemical mechanisms, and of how they respond when perturbed by factors such as medical therapeutics, environmental agents, and genetic variation. Through this understanding, new technologies can be created to improve human health in a variety of medical and environmental applications, and biology-based paradigms can be generated to address many of the diverse challenges facing society.

The BE program’s central aim is to establish a new, biology-based engineering discipline, alongside well established disciplines such as chemical engineering, electrical engineering, and mechanical engineering. At the same time, the program endeavors to assist these engineering and science disciplines in addressing the impact of new processes and products relating to human health and the environment. To meet these objectives, BE comprises faculty with expertise in key areas of engineering, biology, biochemistry, biophysics, toxicology, pharmacology, and other relevant physical/chemical/computational sciences, and who share a goal of integrating central principles to pioneer innovative research and education direction at this nexus.

The program’s premise is that the science of biology is as important to the development of technology and society today as physics and chemistry were in the 20th century, and that the growing ability monitor, assess, and control properties of living organisms at the molecular, cellular, tissue, organ, and systems levels will continue to shape this development. A new generation of engineers and scientists is learning to address problems through their ability to measure, model, and rationally manipulate the technological and environmental factors affecting biological systems. They are applying not only engineering principles to the understanding of how biological systems operate, especially when impacted by genetic, chemical, infectious, or other interventions; but also a synthetic design perspective to creating biology-based technologies for medical diagnostics, therapeutics, and other devices, as well as for application in diverse industries unrelated to health care.

**UNDERGRADUATE STUDY**

**Bachelor of Science in Biological Engineering**

The Biological Engineering Division offers an undergraduate curriculum emphasizing engineering analysis, design, and synthesis in the study of modern biology from the molecular to the systems level. Completion of the curriculum leads to the Bachelor of Science in Biological Engineering and prepares students for careers in diverse fields ranging from the pharmaceutical and biotechnology industries to materials, devices, and ecology. Graduates of the program will be prepared to enter positions in basic research or project-oriented product development, as well as graduate school or further professional study.

The required core curriculum includes a strong foundation in biological and biochemical sciences, which are integrated with engineering principles throughout the entire core. Students who wish to pursue the Bachelor of Science in Biological Engineering are encouraged to complete the Biology General Institute Requirement during freshman year and may delay completion of Physics II until the fall term of sophomore year if necessary. The optional six-unit subject Introduction to Bioengineering, offered during the spring term of freshman year, provides a framework for understanding the role of bioengineering, and the Biological Engineering SB, within the School of Engineering.

Enrollment in the Biological Engineering SB is limited at the present time, and students who wish to pursue this degree must complete the sophomore fall-term subject 20.110 Thermodynamics of Biomolecular Systems with a passing grade in order to apply for admission. This subject also fulfills an SB degree requirement in Biology. Students are also encouraged to take Organic Chemistry I and Differential Equations by the fall term of sophomore year in order to prepare for spring-term sophomore subjects in biological kinetics and programming. The sophomore spring-term curriculum also includes an introductory biological engineering laboratory subject that provides context for the lecture subjects and a strong foundation for subsequent undergraduate research in biological engineering through Undergraduate Research Opportunity Program projects or summer internships.

The advanced subjects required in the junior and senior years introduce additional engineering skills through lecture and laboratory subjects and culminate in a senior design project. These advanced subjects maintain the theme of molecular to systems–level analysis, design, and synthesis based on a strong integration with biology fundamentals. They also include a variety of restricted electives that allow students to develop expertise in one of four thematic areas: systems biology, pharmacology/toxicology, cell and tissue engineering, and microbial systems.

Many of these advanced subjects are jointly taught with other departments in the School of Engineering or School of Science and may fulfill degree requirements in other programs.

**Minor Program in Biomedical Engineering**

An interdepartmental Minor in Biomedical Engineering is available to all undergraduate students. While the total number of subjects required for the minor is eight, all science and engineering majors at MIT already take two or three of these subjects for their major. Students who are not science or engineering majors can use two of the subjects to fulfill Restricted Electives in Science and Technology requirements. The total number of additional subjects required to complete the minor is thus five or six.

The Minor in Biomedical Engineering consists of the following:

**Science Core**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.12</td>
<td>Organic Chemistry I plus</td>
</tr>
<tr>
<td>5.07</td>
<td>Biological Chemistry I or</td>
</tr>
<tr>
<td>7.05</td>
<td>General Biochemistry and</td>
</tr>
</tbody>
</table>

**Engineering Core**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.03</td>
<td>Differential Equations or</td>
</tr>
<tr>
<td>3.016</td>
<td>Mathematical Methods for Materials Scientists and Engineers plus</td>
</tr>
</tbody>
</table>
a subject that applies differential equations to solve systems or macroscopic rate problems including, but not limited to:

- 2.003 Modeling Dynamics and Control I
- 2.005 Thermal-Fluids Engineering I
- 6.002 Circuits and Electronics
- 3.022 Microstructural Evolution in Materials
- 10.301 Fluid Mechanics
- 16.03/16.04 Unified Engineering III–IV
- 22.01 Introduction to Ionizing Radiation

### Biomedical Engineering Core

**Two of the following:**

- 20.110 Thermodynamics of Biomolecular Systems
- 20.309 Biological Engineering II: Instrumentation and Measurement
- 20.310 Molecular, Cellular, and Tissue Biomechanics
- 20.360 Cell and Tissue Engineering
- 20.361 Molecular and Engineering Aspects of Biotechnology
- 20.370 Quantitative Physiology: Cells and Tissues
- 20.371 Quantitative Physiology: Organ Transport Systems
- 20.390 Foundations of Computational and Systems Biology

### Restricted Electives

**One subject from the following:**

- 20.105 Biotechnology and Engineering
- 20.320 Biomolecular Kinetics and Cell Dynamics
- 20.330 Fields, Forces and Flows in Biological Systems
- 20.340 Materials for Biomedical Applications
- 20.342 Molecular Structure of Biological Materials
- 20.411 Cell-Matrix Mechanics
- 20.441 Biomaterials—Tissue Interactions
- 20.451 Design of Medical Devices and Implants
- 20.481 Fundamental Limits of Biological Measurement
- 20.900 Interdisciplinary Research in Biomedical Engineering
- 3.052 Nanomechanics of Materials and Biomaterials
- 6.121 Bioelectronics Project Laboratory
- 6.555 Biomedical Signal and Image Processing
- 6.581 Foundations of Algorithms and Computational Techniques in Systems Biology
- 6.807 Computational Functional Genomics
- 9.29J Introduction to Computational Neuroscience
- 10.28 Biological Engineering Laboratory
- 10.29 Biological Engineering Projects Laboratory
- 16.400 Human Factors Engineering
- 16.423 Aerospace Biomedical and Life Support Engineering
- 16.423 Human Factors Engineering
- 16.423 Aerospace Biomedical and Life Support Engineering
- 22.01 Introduction to Ionizing Radiation
- 22.058 Principles of Tomographic Imaging

---

### Bachelor of Science in Biological Engineering/Course 20

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

**Required Core Subjects**

- 18.03 Differential Equations, 12, REST; 18.02 or 18.014
- 20.110 Statistical Thermodynamics of Biomolecular Systems, 12; 18.02; 3.092; 5.111, or 5.112; 7.012, 7.013, or 7.014
- 5.12 Organic Chemistry, 12, REST; 5.111, 5.112, or 5.091
- 20.109 Laboratory Fundamentals in Biological Engineering, 12, LAB, CI-M; 7.012, 7.013, or 7.014; 8.01; 18.02; 5.112, 5.113, or 5.091; 8.02
- 20.113 Population Genetics, 12; 7.012, 2013; or 7.014
- 20.180 Programming for Biological Engineers, 6; 18.03, 20.109, 20.320, 20.113
- 20.181 Biological Engineering Computation, 6; 20.180
- 5.07 or 7.05 Biochemistry, 12, REST; 5.12
- 7.06 Cell Biology, 12; 203 or 20.113
- 20.310 Molecular, Cellular, and Tissue Biomechanics, 12; 20.110, 18.03
- 20.320 Biomolecular Kinetics and Cellular Dynamics, 12; 20.110, 18.03
- 20.330 Fields, Forces and Flows in Biological Systems, 15; 20.310 or 6.021
- 20.350 Biological Engineering II: Instrumentation and Measurement, 15; 20.310; 20.109 or 7.02; 20.330; 7.06
- 20.380 Senior Biological Engineering Design, 12, CI-M; 20.330, 20.309

**Restricted Electives (Tracks TBD)**

- 21–24

**Course 20 Units That also Satisfy the GIRs (18.03, 5.12, 20.109)**

- 36

**Unrestricted Electives**

- 48

**Total Units Beyond the GIRs Required for SB Degree**

- 195–198

*No subject can be counted both as part of the 17-subject GIRs and as part of the 192 units required beyond the GIRs. Every subject in the student’s Departmental Program will count toward one or the other, but not both.*

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
other subjects in biomedical engineering or related fields with the approval of the minor advisor. Any subject in the Biomedical Engineering Core sequence is also acceptable as a restricted elective after the core requirements are fulfilled. Additional subjects in biomedical engineering are offered at the graduate level, and may be used as electives upon approval by the student’s minor advisor.

**Science/Engineering Elective**

*Graduate-level subject that typically enrolls upper-level undergraduates as well.*

**Laboratory Core**

One subject from the following:
- 20.109 Laboratory Fundamentals in Biological Engineering
- 20.102 Macroepidemiology
- 20.103 Introduction to Physiological Modeling
- 20.104 Chemicals in the Environment: Toxicology and Public Health
- 20.105 Biotechnology and Engineering
- 20.106 Systems Microbiology

**Restricted Electives**

One subject from the following:
- 20.901 Special Topics in Toxicology and Environmental Health
- 20.URG Undergraduate Research Opportunities
- 1.080 Environmental Chemistry and Biology
- 1.725 Chemicals in the Environment: Fate and Transport (TPP51J)
- 1.89 Environmental Microbiology
- 5.07 Biological Chemistry I
- 7.05 General Biochemistry
- 7.06 Cell Biology
- 7.28 Molecular Biology
- 12.807 Atmospheric Chemistry
- 17.32 Environmental Politics and Policy

**Miscellaneous**

*Additional subjects in biomedical engineering are offered at the graduate level, and may be used as electives upon approval by the student’s minor advisor.*

**Minor Program in Toxicology and Environmental Health**

The Biological Engineering Division offers an undergraduate Minor in Toxicology and Environmental Health. This program consists of three required didactic core subjects and one laboratory subject, as well as one restricted elective. The prerequisites for the core subjects are 5.111/5.112 Principles of Chemical Science or 3.091 Introduction to Solid State Chemistry plus 7.012/7.013/7.014 Introductory Biology.

**Core Subjects**

Three subjects from the following:
- 20.102 Macroepidemiology
- 20.103 Introduction to Physiological Modeling
- 20.104 Chemicals in the Environment: Toxicology and Public Health
- 20.105 Biotechnology and Engineering
- 20.106 Systems Microbiology

**Laboratory Core**

One subject from the following:
- 20.109 Laboratory Fundamentals in Biological Engineering
- 5.310 Laboratory Fundamentals in Biological Engineering
- 7.02 Introduction to Experimental Biology and Communication
- 20.400 Perspectives in Biological Engineering
- 20.410 Perspectives in Molecular, Cellular, and Tissue Biomechanics
- 20.420 Biomolecular Kinetics and Cellular Dynamics
- 20.430 Fields, Forces, and Flows in Biological Systems

**Graduate Study**

**Doctoral Program in Biological Engineering**

The Biological Engineering Division offers a PhD program—and, in certain cases, an SM degree—with two tracks, one in bioengineering and another in applied biosciences. These tracks complement one another as a reflection of the importance of approaching quantitative biological and biomedical problems from the two perspectives. Students in either track may pursue research projects in any area by agreement with their research supervisor.

Graduate students in the Biological Engineering Division can carry out their research as part of a number of multi-investigator, multi-disciplinary research centers at MIT, including the Center for Biomedical Engineering, the Biotechnology Process Engineering Center, the Center for Environmental Health Sciences, and the Division of Comparative Medicine. These opportunities include collaboration with faculty in the Schools of Engineering and Science, the Center for Cancer Research, and the Whitehead Institute for Biomedical Research, along with the Harvard University School of Medicine, Harvard University School of Dental Medicine, Harvard School of Public Health, and Boston University School of Medicine.

**Bioengineering Track**

Students admitted to the bioengineering track typically have a bachelor’s or master’s degree in engineering. During that first year, students pursue a unified core curriculum, in which engineering approaches are used to analyze biological systems and technologies over a wide range of length and time scales. The four core bioengineering subjects are:

- 20.400 Perspectives in Biological Engineering
- 20.410 Molecular, Cellular, and Tissue Biomechanics
- 20.420 Biomolecular Kinetics and Cellular Dynamics
- 20.430 Fields, Forces, and Flows in Biological Systems

For further information on the undergraduate programs, please visit the Biological Engineering website at [http://web.mit.edu/be/](http://web.mit.edu/be/) or contact the BE Academic Office, Room 56-651, MIT, 617-253-1712.
device systems levels. Foundational coursework in biochemistry and molecular cell biology is required, either before admission or during the first year of graduate study.

To enhance depth and breadth, the core subjects are supplemented by electives in the biological sciences and engineering. For doctoral candidates, at least one of these must be a graduate-level biology subject, two must be courses in engineering science, and another must be a subject in one of the following areas: biomaterials, biological instrumentation and measurement, or bioinformatics and computational biology. The written part of the doctoral qualifying examinations, centered on the core curriculum, is taken after the second term.

The student selects a research advisor and begins research before the end of the first year. The oral part of the doctoral qualifying exams, which focuses on the student’s area of research, is taken during the second year. Approximately five years of total residence are needed to complete the doctoral thesis and other degree requirements.

The bioengineering track educates students to use engineering principles in the analysis and manipulation of biological systems, allowing them to solve problems across a spectrum of important applications. The curriculum is inherently interdisciplinary in that it brings together engineering and biology as fundamentally as possible and cuts across the boundaries of the traditional engineering disciplines.

The faculty members associated with this track possess a wide range of research interests within bioengineering. Areas in which students may specialize include biological and physiological transport phenomena; biological imaging and functional measurement; biomolecular engineering; cell and tissue engineering; computational modeling of biological and physiological systems; bioinformatics; design, discovery and delivery of molecular therapeutics; molecular, cell, and tissue biomechanics; and new tools for genomics, proteomics, and glycomics.

**Applied Biosciences Track**

Students admitted to the applied biosciences track typically have a bachelor’s or master’s degree in chemistry, biology, physics, or a related field. During the first year, students pursue a unified core curriculum, in which basic science approaches are applied to problems in the health and disease aspects of biomedical science. The four core subjects are:

- **20.400** Perspectives in Biological Engineering
- **20.420** Biomolecular Kinetics and Cellular Dynamics
- **20.440** Analysis of Biological Networks
- **20.450** Molecular and Cellular Pathophysiology

These subjects bring central scientific principles to bear on the operation of biological systems from molecular to cell to tissue to organismal levels. Foundational coursework in physics, calculus, organic chemistry, biochemistry, physical chemistry/biophysics/engineering, and cell biology/molecular biology/genetics is required, either before admission or during the first year of graduate study.

To enhance depth and breadth, the core subjects are supplemented by elective subjects. Doctoral candidates are expected to take elective courses in biochemistry and cell biology (or an additional graduate-level biology subject if both are waived), one graduate-level applied bioscience subject (selected from a short list of subjects not in the core), and two courses from among the core graduate offerings of an established department. The written part of the doctoral qualifying examinations, centered on the core curriculum, is taken after the second semester. The students select a research advisor and begin research before the end of the first year. The oral part of the doctoral qualifying examinations, which focuses on the student’s area of research, is taken during the second year. Approximately five years of total residence are needed to complete the doctoral thesis and other degree requirements.

The applied biosciences track complements the bioengineering track (and the Computational and Systems Biology graduate program) by focusing on understanding the interactions of organisms with chemical, biological, and physical agents from the molecular to the systems level. The goal here is to apply systems approaches to studying the chemical and molecular pathways by which exogenous and endogenous agents induce toxicity and cause disease in humans; to establishing the molecular mechanisms of drug actions, with the longer-term aim of developing improved therapeutics; to establishing mechanisms of microbial pathogenesis; and to understanding and manipulating immune function.

Systems biology is an emerging field that involves quantitative study of biological processes as integrated systems rather than as isolated parts. This goal of defining the behavior of the myriad of individual molecules requires quantitative models to unify the individual disciplines of physical chemistry, biochemistry, molecular biology, and cell physiology, as well as new tools for the simultaneous measurement of biological components, including small molecules, proteins, nucleic acids and complex carbohydrates.

The applied biosciences track provides rigorous training in the basic sciences, with application of chemistry, mathematics, biochemistry, molecular biology, cell biology, genetics, toxicology, and pharmacology to problems in human health and disease. Students receive preparation for careers in academic institutions, government agencies, and industry involving the application of modern methods of chemical, molecular, biological, and genetic analysis to the characterization of health risks.

Areas of research specialization within the program include development of in vitro models of the immune system and lymphoid tissue; development of molecular methods for direct measurement of mutations in humans; metabolism of foreign compounds; genetic toxicology; the molecular aspects and dosimetry of interactions between mutagens and carcinogens with nucleic acids and proteins; molecular mechanisms of DNA damage and repair; design and mechanisms of action of chemotherapeutic agents; environmental carcinogenesis and epidemiology; molecular mechanisms of carcinogenesis; cell physiology; extracellular regulation and signal transduction; and molecular and pathologic interactions between infectious microbial agents and carcinogens. Interdisciplinary in nature, the program and other programs and departments share an interest in human pathophysiology, molecular pharmacology, and environmental health.

**Master of Engineering in Biomedical Engineering**

The Master of Engineering in Biomedical Engineering (MEBE) is offered jointly by the Biologi-
program should submit a standard MIT graduate application by the end of their junior year and are informed of the decision by the end of that summer. Additional information on application procedures, together with information on track-specific objectives and program requirements, can be obtained by contacting Professor Ioannis Yannas at 617-253-4469 for the biological engineering track, or Professor Roger Mark at 617-253-7818 for the medical engineering track, or the BE Academic Office, Room 56-651, 617-253-1712, or HST’s Office of Academic Affairs, Room E25-518, 617-258-7084.

Biological Engineering Track
In addition to thesis credits, at least 66 units of coursework are required. At least 42 of these subject units must be from H-level graduate subjects. The remaining units may be satisfied with G-level subjects, or in some cases, with advanced undergraduate subjects. Of the 66 units, a minimum distribution in each of three categories is specified below.

Bioengineering Core
24 units selected from:
20.410 Molecular, Cellular, and Tissue Biomechanics
20.420 Biomolecular Kinetics and Cellular Dynamics
20.430 Fields, Forces, and Flows in Biological Systems

Biomedical Engineering Electives
24 units selected from:
A selection of G- or H-level subjects from various departments in the School of Engineering and HST. A list of suggested subjects is available from the BE Academic Office, Room 56-651.

Bioscience Elective
One biological science subject in addition to organic chemistry and biochemistry. This must be a laboratory subject if one was not taken as part of the student's undergraduate curriculum.

Thesis
The student is required to complete a thesis consisting of an original work of research, design, or development with substantial engineering content. A detailed thesis proposal is required at the end of the spring term of the fourth year, with the expectation that the work continues during the summer and is completed by the end of the spring term of the fifth year. The research may be done at MIT, HMS, or the teaching hospitals under the supervision of a Harvard or MIT faculty member. An MIT faculty member eligible to supervise graduate theses in the School of Engineering must supervise the thesis. Co-supervision of theses by faculty members in other departments or at HMS is suitable if the main thesis supervisor is a faculty member in the School of Engineering. A list of appropriate faculty members can be found in each department listing in Part 2.

For further information on the graduate programs, please visit the Biological Engineer-
Leaders for Manufacturing Program

The Leaders for Manufacturing (LFM) program combines graduate education in engineering and management for those with two or more years of work experience who aspire to leadership positions in manufacturing or operations companies. This rigorous 24-month program combines subjects in technology and management. A required 6.5-month internship provides opportunity to complete a research project on site at one of LFM's partner companies. The internship leads to a dual-degree thesis, culminating in two master's degrees—an SM in management or an MBA, and an SM in engineering from the Division of Biological Engineering. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description in the Engineering Systems Division section in Part 2 or visit http://lfm.mit.edu/.

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Sujan Kabir, MD  
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S. Raguram, PhD  
Zeliang Zhao, MD
Chemical engineering encompasses the translation of molecular information into discovery of new products and processes. It involves molecular transformations—chemical, physical, and biological—with multi-scale description from the submolecular to the macroscopic, and the analysis and synthesis of such systems. The chemical engineer is well prepared for a rewarding career in a strikingly diverse array of industries and professional arenas. Whether these industries are at the cutting edge—e.g. nanotechnology or biotechnology—or traditional, they depend on chemical engineers to make their products and processes a reality. The effectiveness of chemical engineers in such a broad range of areas begins with foundational knowledge in chemistry, biology, physics, and mathematics. From this foundation, chemical engineers develop core expertise in engineering thermodynamics, transport processes, and chemical kinetics, creating a powerful and widely applicable combination of molecular knowledge and engineering problem solving. To cope with complex, real-world problems, chemical engineers develop strong synthetic and analytic skills. Through creative application of these chemical engineering principles, chemical engineers create innovative solutions to important industrial and societal problems in areas such as development of clean energy sources, advancement of life sciences, production of pharmaceuticals, sustainable systems and responsible environmental stewardship, and discovery and production of new materials.

The Department of Chemical Engineering at MIT offers three undergraduate programs. Course 10 leads to the Bachelor of Science in Chemical Engineering through a curriculum accredited by the Accreditation Board for Engineering and Technology (ABET). Course 10-B leads to the Bachelor of Science in Chemical-Biological Engineering, which includes the basic engineering core from the Course 10 degree and adds material in basic and applied biology. ABET accreditation for this degree is anticipated. Course 10-C leads to the Bachelor of Science without specification; this is not accredited and requires fewer chemical engineering subjects. Many undergraduates take advantage of graduate-level subjects in their upper-class years. Undergraduate students are also encouraged to participate in research through the MIT UROP program.

The department offers a broad selection of graduate subjects and research topics leading to advanced degrees in chemical engineering. Multidisciplinary approaches are highly valued, leading to strong ties with other MIT departments. In addition, the department maintains alliances, arrangements, and connections with institutions and industries worldwide. Areas for specialization include, but are not limited to: biochemical engineering, biomedical engineering, biotechnology, chemical catalysis, chemical process development, environmental engineering, fuels and energy, polymer chemistry, surface and colloid chemistry, systems engineering, and transport processes. Additional information may be found under Graduate Study below and on the department’s website.

The School of Chemical Engineering Practice (described below), leading to five-year bachelor’s and master’s degrees, involves one term of work under the direction of an Institute staff member resident at Practice School sites. This program provides students with a unique opportunity to apply basic professional principles to the solution of practical industrial problems.

UNDERGRADUATE STUDY

The undergraduate curriculum in chemical engineering provides basic studies in physics, biology, and mathematics, a concentration in chemistry, and a strong core of chemical engineering. The four-year undergraduate programs provide students with the fundamentals of the discipline and allow some room for focus in subdisciplines or subjects that strengthen their preparation for advanced work.

In addition to science and engineering, students take an integrated sequence of subjects in the humanities and social sciences. Specific course selection allows students to meet individual areas of interest. The curriculum provides a sound preparation for jobs in industry or government, and for graduate work in chemical engineering.

Chemical engineering also provides excellent preparation for careers in medicine and related fields of health science and technology. The department’s strong emphasis on chemistry and biology provides excellent preparation for medical school. Students interested in medical school work with their faculty and premedical advisor to create the best program. A minor in biomedical engineering is also available.

Bachelor of Science in Chemical Engineering/Course 10
This degree is intended for the student who seeks a broad education in the application of chemical engineering in the areas of biochemical and biomedical technologies. The degree requirements include core chemical engineering subjects and additional subjects in biological sciences and applied biology. This degree is excellent preparation for students also considering the biomedical engineering minor or medical school.

Students who decide early to major in either Course 10 or Course 10-B are encouraged to take subjects such as 5.11/5.111/5.112 Principles of Chemical Science, 5.12 Organic Chemistry I, and 10.10 Introduction to Chemical Engineering in their freshman year. Then 5.60, 18.03, 7.012/7.013/7.014, 10.213, and 10.301 may be taken in the sophomore year. The student is then well positioned for more in-depth and specialized subjects in the third and fourth years.

Some students may wish to defer choice of a major field or exercise maximum freedom during the first two years. If the Restricted Electives in Science and Technology (REST) Requirement subjects chosen in the second year include 18.03 and two subjects in the fields of fluid mechanics, thermodynamics, chemistry, biology, or chemical engineering, students can generally complete the requirements for a de-
Bachelor of Science in Chemical Engineering/Course 10

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
<th>Units</th>
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</thead>
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<tr>
<td>Science Requirement</td>
<td>6</td>
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<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
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<tr>
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<td>Laboratory Requirement (can be satisfied by 5.310)</td>
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</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td><strong>17</strong></td>
<td></td>
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</tbody>
</table>

### Communication Requirement
The program includes a Communication Requirement of 4 subjects:
- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

### PLUS Departmental Program
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

#### Required Subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.12 Organic Chemistry I, 12, REST; 5.111*</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>5.07 Biological Chemistry I, 12, REST; 5.12 or 7.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.310 Laboratory Chemistry, 12, LAB; 5.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.60 Thermodynamics and Kinetics, 12, REST; 18.02, 5.111*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0 Introduction to Chemical Engineering, 12; 8.01, 18.01, 5.111*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.213 Chemical and Biological Engineering Thermodynamics, 12; 5.60, 10.10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**One of the following four subjects:**
- 10.26 Chemical Engineering Projects Laboratory, 15, CI-M; 5.310 or 7.02; 10.302
- 10.27 Chemical Engineering Processes Laboratory, 15, CI-M; 5.310, 10.32, 10.37
- 10.28 Biological Engineering Lab, 15, CI-M; 5.310, 7.02, or 10.702; 7.05 or 5.07
- 10.29 Biological Engineering Projects Laboratory, 15, CI-M; 5.310, 7.02, or 10.702; 10.302

#### Restricted Electives

One subject in Chemical Engineering, except 10.UR, 10.URG, 10.ThU, 10.04, 10.792 J, 10.801–10.816, 10.90–10.999, plus one laboratory subject from the following list:
- 3.014 Materials Laboratory, 12, CI-M, LAB
- 5.155/6.525 Microelectronics Processing Technology, 12, CI-M; permission of the instructor
- 5.32 Intermediate Chemical Experimentation, 15, CI-M; 5.310*, 5.13, 5.60
- 7.021 Introduction to Experimental Biology and Communication, 18, CI-M, LAB; 7.012*
- 10.467 Polymer Science Laboratory, 15, CI-M; 5.12, 5.310*
- 10.468 Chemical Engineering Projects Laboratory(1), 15, CI-M; 5.310 or 10.37, 5.310
- 10.28 Biological Engineering Lab(1), 15, CI-M; 5.310 or 7.02; 10.302
- 10.702 Introductory Experimental Biology and Communication, 18, CI-M, LAB; 7.012*

#### Departmental Program Units That also Satisfy the GIRs

- 9.702* and 9.704* (36)
- 10.041 and 10.042 (16)
- 10.046, 10.047, and 10.048 (6)

#### Unrestricted Electives

- 48

**Total Units Beyond the GIRs Required for SB Degree**

198

No subject can be counted both as part of the 17-subject GIRs and as part of the 198 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

### Notes

- *Alternate prerequisites are listed in the subject description.
- (1) Either 10.26, 10.27, 10.28, or 10.29 must be taken as a Departmental Requirement and cannot also be used to satisfy this Restricted Laboratory Requirement.
- For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

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Bachelor of Science/Course 10-C

The curriculum for students in Course 10-C involves basic subjects in chemistry and chemical engineering. Instead of continuing in depth in these areas, students can add breadth by study in another field, such as another engineering discipline, biology, biomedical engineering, economics, or management. Course 10-C is attractive to students who wish to specialize in an area such as those cited above while simultaneously gaining a broad exposure to the chemical engineering approach to solving problems.

Departmental requirements for Course 10-C are:

- 5.11/5.111/5.112, 5.60, 10.213, 10.301, and 10.302
- plus one subject from the following:
  - 3.014, 3.155/6.152, 5.32, 7.021/10.702, 10.26, 10.28, 10.29 or 10.467;
  - and an additional subject from the above list or the following:
    - 1.060, 1.096, 6.021J, 6.033, 6.111, 6.805, 14.05, 14.06, 15.279 or 15.301

All of the above restricted elective subjects satisfy the Institute CI-M requirement. Students must also complete 18 units beyond the GIRs; subjects chosen to complete these units must form a coherent program, and any subject chosen from the last list must be part of this coherent program.
Students planning to follow this curriculum should discuss their interests with their faculty advisor in the department at the time they decide to enter the Course 10-C program, and submit to Dr. Johnston in the department’s Undergraduate Office a statement of goals and a coherent program of subjects no later than spring term of junior year. Please direct questions about this program to Dr. Johnston.

**Five-Year Programs and Joint Programs**

In addition to offering separate programs leading to the Bachelor of Science and Master of Science in Chemical Engineering, the department offers a program leading to the simultaneous award of both degrees at the end of five years. A detailed description of this program is available from the Graduate Student Office. Students in the five-year program normally enroll in the School of Chemical Engineering Practice.

For chemical engineering students interested in nuclear applications, the Department of Chemical Engineering and the Department of Nuclear Engineering offer a five-year program leading to the joint Bachelor of Science in Chemical Engineering and Master of Science in Nuclear Engineering. Such programs are approved on an individual basis between the registration officers of the two departments.

**Inquiries**

Additional information concerning undergraduate academic and research programs may be obtained by writing to Dr. Barry S. Johnston, undergraduate officer, Department of Chemical Engineering, Room 66-368, MIT, Cambridge, MA 02139-4307, 617-258-7141, fax 617-258-0546. For information regarding admissions and financial aid, contact the Admissions Office, Room 3-108, telephone 617-253-4791.

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**GRADUATE STUDY**

Graduate study provides both rigorous training in the fundamental core discipline of chemical engineering and the opportunity to focus on specific subdisciplines. In addition to completing four core subject requirements in thermodynamics, reaction engineering, numerical methods, and transportation phenomena, students select a research advisor and area for specialization, some of which are discussed below.

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**Bachelor of Science in Chemical-Biological Engineering/Course 10-B**

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**General Institute Requirements (GIRs)**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement (can be satisfied from among 5.03, 5.12, 5.60, 7.03, 7.05, 10.301, and 10.03 or 10.034 in the Departmental Program)</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement (can be satisfied by 7.02 or 10.702)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total GIR Subjects Required for SB Degree**

17

**Communication Requirement**

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

**PLUS Departmental Program**

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

### Required Subjects

- **5.12** Organic Chemistry I, 12, REST; **5.111**
- **5.60** Thermodynamics and Kinetics, 12, REST; **18.02**, **5.111**
- **7.02** Introduction to Experimental Biology, 18, CI-M, LAB; **7.012** or **10.702**
- **7.03** Genetics, 12, REST; **7.012**
- **7.05** General Biochemistry, 12, REST; **5.12**, **7.012** or **5.07** Biological Chemistry I, 12, REST; **5.12**
- **7.06** Cell Biology, 12, **7.03**, **7.05** or **5.07**
- **10.10** Introduction to Chemical Engineering, 12; **8.01**, **18.01**, **5.111**
- **10.213** Chemical and Biological Engineering Thermodynamics, 12; **5.60**, **10.10**
- **10.28** Biological Engineering Laboratory, 15, CI-M; **5.310** or **7.02** or **10.702**, **7.05** or **5.07** or **10.29** Biological Engineering Projects Laboratory, 15, CI-M; **5.310** or **7.02** or **10.702**, **10.302**
- **10.301** Fluid Mechanics, 12, REST; **18.03**, **10.10**
- **10.302** Transport Processes, 12; **5.60**, **10.213**, or **10.301**
- plus **10.37** Chemical Kinetics and Reactor Design, 9; **5.60**, **10.301**
- **10.490** Integrated Chemical Engineering I, 8; **10.37**
- **10.491** Integrated Chemical Engineering II, 8; **10.490**
- plus two of the following three subjects:
  - **10.492** Integrated Chemical Engineering III, 4; **10.490**
  - **10.493** Integrated Chemical Engineering IV, 4; **10.490**
  - **10.494** Integrated Chemical Engineering V, 4; **10.490**
- **18.03** Differential Equations, 12, REST; **18.01** or **18.014** or **18.034** Differential Equations, 12, REST; **18.01** or **18.014**

**Total Units Beyond the GIRs Required for SB Degree**

198

No subject can be counted both as part of the 17-subject GIRs and as part of the 198 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

**Notes**

*Alternate prerequisites are listed in the subject description.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
Biotechnology and Bioengineering. Biology, along with chemistry and physics, has become a foundational science of chemical engineering. Rapid advances in genetics and molecular and cell biology have created enormous opportunities for chemical engineers as this new enabling science must be translated into diverse technologies to achieve industrial and commercial reality. Applications include delivery of therapeutics (not only pharmaceuticals but also cellular and genetic elements), tissue engineering (to repair or reconstruct organ function), and extracorporeal treatments such as toxin removal and cell separations, as well as a fundamental understanding of cell and tissue physiology in terms of reaction kinetics and transport phenomena. The chemical engineering paradigm is broadly emulated in the development of therapies, devices, and materials for biomedical applications and strengthens the role of chemical engineers in modern health care technology.

Another biotechnological dimension of particular importance to chemical engineering is the deployment of biological systems and processes for the synthesis and production of specialty and bulk chemicals, fuels, and materials. By reconfiguring the structure and regulation of the bioreaction networks of microbial cells, it is now possible to harness the incredible versatility and efficiency of microbes for the synthesis of numerous existing and new products by environmentally benign processes using renewable resources. This area of application, metabolic engineering, creates new methods for product synthesis with the accompanying bioprocessing and scale-up opportunities. A new research and education initiative in bioinformatics brings the fundamentals of systems theory to problems of integrating and interpreting large biological data sets in the context of metabolic engineering, genomics, and drug design. Chemical engineering faculty are also involved in the Center for Biomedical Engineering, created to enhance interdisciplinary research and education at the intersection of engineering, molecular and cell biology, and medicine. Many research collaborations exist with the Department of Biology, the Whitehead Institute, and the Harvard and Boston University medical schools.

Chemical Engineering Systems and Process Control. In an era of structural changes in the chemical and biochemical industries, the computer-aided engineer is challenging conventional modes throughout the whole spectrum of activities such as product design, process conception and design, process engineering, control and operations, safety, and environmental protection. Extensive research efforts are currently under way in all of the above areas, supported by state-of-the-art computer facilities and software utilities.

Methodologies from computer science, applied math, operations research, and control and estimation theory are being combined vigorously with various computer-aided engineering activities, leading to new prototypes for industrial analysis and design.

Characteristic examples of current research projects that shape new prototypes for process systems engineering include process simulation; design of batch processes; design of molecules with desired properties; process synthesis; operability, control, and safety; development of biotechnological processes; intelligent databases and graphic interfaces; synthesis of control systems; and intelligent controllers.

Catalysis and Reaction Engineering. Catalysis is by far the most important process in the manufacturing of chemicals and in the refining of fuels for transportation and power. Catalysis is also the main process in reducing impurities in fuels, and thus solving environmental problems from combustion products. Recent advances in new catalytic materials are opening the doors to better technologies. Modern spectroscopic and computational techniques are providing powerful probes into the nature of catalytic action.

The heart of most chemical processes is the chemical reactor, which determines the overall process success. The overall performance is determined by the interactions of fluid mechanics, mixing, and transport phenomena with chemical kinetics. Rational design and operation of both catalysts and reactors are the objectives of this research area.

Microfabrication techniques and scale-up by replication have fueled spectacular advances in the electronics industry, and they are now creating new opportunities for reaction engineering. Collaborations between the Chemical Engineering and the Electrical Engineering and Computer Science departments have microfabricated chemical systems with feature sizes in the micron to hundreds of micron range and reaction components integrated with sensors and actuators. Microfluidic systems involving highly reactive, potentially hazardous, or toxic compounds are a focus of this work.

Colloid Science and Separations. Colloid science, specifically as it applies to structured fluids, is an interdisciplinary program drawing on the fields of engineering, physics, chemistry, biology, and medicine. It is a scientifically challenging area with important practical benefits, not only in industrial processes but also in biomedical applications.

Structured fluids are solutions composed of microstructures dispersed in a solvent. These microstructures may be polymers, biopolymers (such as proteins and viruses), colloidal particles, surfactant aggregates (such as micelles, vesicles, and microemulsion droplets), or clathrates and hydrates. Structural fluids are important in fields as diverse as biological and environmental separations, drug delivery systems, transport of cholesterol in the body, tertiary oil recovery, cosmetics, food processing, synthesis of ultrafine particles for microelectronic and ceramics applications, and detergency and wetting.

Students can draw on the theoretical tools of statistical mechanics, thermodynamics, liquid-state theory, Monte-Carlo and molecular dynamics simulations, colloid and interface science, transport, and kinetics. A rich array of experimental techniques can also be employed in thesis research, including small-angle X-ray and neutron scattering; quasi-elastic light scattering; NMR; fluorimetry, infrared, and impedance spectroscopies; interfacial tensiometry; viscometry; calorimetry; interferometry; and various scanning-probe microscopies.

The field of separation science is also of major importance to the chemical, metallurgical, and biochemical industries and plays a leading role in the remediation of environmental problems. Microstructured colloidal fluids provide an interesting opportunity to mediate solute-solvent interactions, and thus to enhance separation selectivities. Examples include block copolymer micelles and tailored magnetic nanoparticles for the removal of trace contaminants from surface and ground waters, and two-phase aqueous polymer solutions or phase-separated micellar systems for the selective separation and concentration of biological species such as proteins and viruses. Stimuli-responsive gels can be used for dynamically
controlled separation of proteins and other macromolecular species. Magnetic nanoparticles are also used for the selective recovery of biologicals from fermentation media, and for the magnetophoretic separation of nonmagnetic submicron particles.

**Energy and Environment.** Energy and environmental problems provide increasing opportunities for contributions by chemical engineers. Research to reduce adverse effects on the environment associated with energy conversion and use continues to be a major activity in the department. An important area is concerned with fundamental physical and chemical processes related to emission sources and control and environmental remediation. The second area focuses on the development of process design and operating procedures that can incorporate multiple objectives, including economic considerations, environmental performance, safety, control, and product quality. The third area explores methods for developing chemistry and molecular systems that preclude environmental problems. Examples include recyclable polymers; ecologically sound detergents; processes for removing trace contaminants from water or gas streams before discharge; solvents and processes that minimize waste-treatment requirements; novel separation methods involving magnetic colloids; new catalysts for control of emissions; microchemical reactors for on-site, on-demand manufacturing of hazardous chemicals; and computational chemistry directed towards understanding environmentally important problems. A fourth area considers alternative energy supplies from geothermal renewable resources and clathrate hydrates, focusing on a wide range of topics from advanced drilling methods to hydrochemical effects in reservoirs.

**Transport Processes and Thermodynamics.** Research in transport processes and thermodynamics provides the foundation for many new and evolving technologies in areas ranging from biotechnology to microelectronics. Fundamental studies underway are at the forefront of scientific disciplines such as thermodynamics, continuum and statistical mechanics, quantum and classical molecular theory, heat and mass transfer, Newtonian and non-Newtonian fluid mechanics, interfacial phenomena, and applied mathematics. Many departmental faculty have research interests that fall into these areas, and their projects offer stimulating fundamental studies motivated by application. Current work involves the study of transport in heterogeneous media and at interfaces, microfluidics, transport in biological systems, chemically reacting flows, supercritical fluids, surfactants, and polymer rheology. The experimental work uses state-of-the-art equipment, and theoretical approaches involve both analytical and numerical methods.

**Polymers.** Polymers comprise a large fraction of the total production of the chemical industry. Their unique macromolecular structure is rich and complex, and requires understanding of relationships between their molecular architecture and physical properties. As polymers continue to replace existing materials in certain applications and open up interesting new areas of technology, greater understanding is required at various levels, ranging from the molecular to the continuum. Chemical engineers contribute to the polymer field in numerous areas of activity such as polymer processing, polymer rheology, structure-property relationships, design of polymers and polymer synthesis and characterization, and interactions among these different areas. In addition to a program of graduate study in polymers within the department, opportunities exist to participate directly and indirectly in the activities of the interdepartmental Program in Polymer Science and Technology.

**Surface and Materials Chemistry.** The study of surface chemistry and surface physics is central to the understanding of many chemical engineering processes. In the department, both fundamental and applied research is conducted in many areas of gas-solid and colloidal surface science.

The understanding of gas-solid kinetics is crucial in the study of heterogeneous catalysis and the fabrication of integrated circuits. Using new and rapidly expanding techniques of surface probes, researchers are exploring the kinetics of catalytic processes, plasma etching of integrated circuits, and chemical vapor deposition of thin films. Typical techniques used include X-ray photoelectron spectroscopy, Auger spectroscopy, modulated beam scattering, mass spectrometry, laser-induced fluorescence, electron microscopy, and BET measurements.

Surface chemistry is applied to novel, ultrafine materials of 1-10 nm. Such nanostructured materials have an extremely high surface-to-volume ratio, and their surface structure is linked to unusual, size-dependent properties that are promising for advanced ceramic, catalytic, electronic, and optical applications.

**School of Chemical Engineering Practice**

Since 1916, the David H. Koch School of Chemical Engineering Practice has been a major feature of the graduate education in the department. In this unique program, students receive intensive instruction to broaden their education not only in the technical aspects of the profession, but also in communication skills and human relations, which are frequently decisive factors in the success of an engineering enterprise. The Practice School program stresses problem solving in an engineering internship format, where students undertake projects at industrial sites under the direct supervision of resident MIT faculty. Credit is granted for participation in the Practice School in lieu of preparing a master’s thesis.

The operation of the Practice School is similar to that of a small consulting company. The resident staff work closely with the technical personnel of the host companies in identifying project assignments with significant educational merit, and with solutions that make important contributions to the operation of the company.

During Practice School, students work on three or four different projects. Groups and designated group leaders change from one project to another, giving every individual an opportunity to be a group leader at least once. Students in the Practice School program are required to demonstrate proficiency, or take one graduate subject, in each of the following areas: thermodynamics, heat and mass transfer, applied process chemistry, kinetics and reactor design, systems engineering, and applied mathematics.

**Master of Science in Chemical Engineering**

Programs for the Master of Science in Chemical Engineering usually are arranged as a continuation of undergraduate professional training, but at a greater level of depth and maturity. The general requirements for a master’s program are given in the section on Graduate Education in Part 1. To complete the requirement of at least 66 subject units, of which 42 units must be in H-level subjects, together with an acceptable thesis, generally takes four terms.
Master of Science in Chemical Engineering Practice

The unit requirements for the Master of Science in Chemical Engineering Practice (Course 10-A) are the same as those for the Master of Science in Chemical Engineering, except that 48 units of Practice School experience replace the master’s thesis.

In some cases, Bachelor of Science graduates of this department can meet the requirements for the Master of Science in Chemical Engineering Practice (Course 10-A) in two terms. Beginning in September following graduation, students complete the required coursework at the Institute. The spring term is spent at the Practice School field stations. Careful planning of the senior year schedule is important.

For students who have graduated in chemical engineering from other institutions, the usual program of study for the Master of Science in Chemical Engineering Practice involves two terms at the Institute followed by the field station work in the Practice School. Graduates in chemistry from other institutions normally require an additional term.

Master of Science in Technology and Policy

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 TPP 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 in the Engineering Systems Division section Part 2 or visit http://tppserver.mit.edu/.

Doctor of Science or Doctor of Philosophy

Admission to the doctoral program is granted only after the doctoral candidate has passed a written and oral general examination. Given in January and May, the examinations are usually taken at the end of the first term in residence as a graduate student. It is not necessary to complete a master’s program in order to obtain a doctorate.

The requirements for the doctoral degree include a program of advanced study, a minor program, a biology requirement, and a thesis. The program of advanced study and research is normally carried out in one of the fields of chemical engineering under the supervision of one or more faculty members in the Department of Chemical Engineering. A thesis committee of selected faculty monitors the doctoral program of each candidate.

Doctor of Philosophy in Chemical Engineering Practice

This degree program provides educational experience that combines advanced work in manufacturing, independent research, and management. The program is built on the outstanding research programs within the department, the unique resources of the David H. Koch School of Chemical Engineering Practice, and the world-class resources of the Sloan School of Management. Students are prepared for a rapid launch into positions of leadership in industry and provided with a foundation for completion of an MBA degree.

The program consists of three major parts: the first year is devoted to coursework and the Practice School, the two middle years are devoted to research, and the final year is completed in the Sloan School of Management. In addition, an integrative project combines the research and management portions of the program.

Students in the PhD in Chemical Engineering Practice (PhDCEP) program must pass the department’s written and oral examinations. The progress of their research is monitored by a faculty committee, and the final thesis document is defended in a public forum. The normal completion time should be four calendar years for the PhDCEP program.

Other Graduate Opportunities

The Joint Program with the Woods Hole Oceanographic Institution is intended for students whose primary career objective is oceanographic engineering.

The Program in Polymer Science and Technology is intended for students who seek a Doctor of Science or Doctor of Philosophy degree with a focus on macromolecular science and engineering. These programs are described in Interdisciplinary Graduate Programs in Part 2.

Financial Support

The department has a wide variety of financial support options for graduate students, including teaching and research assistantships, fellowships, and loans. Information about financial assistance may be obtained by writing to the
Graduate Student Office, but consideration for awards cannot be given before admissions decisions have been made.

Inquiries
For additional information concerning graduate programs, admissions, financial aid, and assistantships, contact the Graduate Student Office, Department of Chemical Engineering, Room 66-366, MIT, chemegrad@mit.edu.

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Professor of Chemical Engineering, Emeritus
The Department of Civil and Environmental Engineering focuses on interactions between human activities and the natural environment. Its mission is to use science, engineering, and policy to improve quality of life. This includes intelligent use of natural resources such as the raw materials, energy, and ecosystems needed to sustain modern society. It also includes design of functional and environmentally compatible facilities and infrastructure. Within this broad context, the Department of Civil and Environmental Engineering is especially concerned with:

- Better understanding of natural cycles, systems, and processes relevant to human activities
- Use of natural analogs to help design new materials, industrial processes, and infrastructure systems
- Development of new building and transportation technologies
- Advances in information infrastructure and logistics
- Creation of attractive and sustainable physical environments

An education in civil and environmental engineering provides an excellent foundation for careers in fields as diverse as engineering design, education, law, medicine, and public health, as well as for graduate study in engineering and science. Our graduates teach and carry out research in universities, work for large firms, start their own businesses, and take positions in government and nonprofit organizations. As pressures on limited natural resources grow, there will be increasing demand for engineers who understand how to make best use of these resources in the products and services they design. The department’s undergraduate program recognizes this need by providing background in science and engineering fundamentals while also emphasizing hands-on design projects and case studies that provide context and motivation. Students are taught how to combine theory, measurement, and modeling to develop a good understanding of the problem at hand and to point the way to desirable solutions.

The department offers two designated undergraduate degrees accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET). The Bachelor of Science in Civil Engineering provides a solid foundation for practice in both classical and newly developing areas of civil engineering, including structural analysis and design, engineering materials, geotechnical analysis and design, sustainable built environments, and transportation and logistics. The Bachelor of Science in Environmental Engineering Science emphasizes the fundamental physical, chemical, and biological processes necessary for understanding the interactions between man and the environment. Issues considered include the provision of clean and reliable water supplies, flood forecasting and protection, development of renewable and nonrenewable energy sources, causes and implications of climate change, and the impact of human activities on natural cycles. Both programs provide awareness of the socio-political context in which civil and environmental engineering problems are solved. Premedical students may satisfy medical school entrance requirements while earning the accredited degree in environmental engineering science with proper planning of their program. A third degree is offered for students who want more flexibility. Typical examples are students who will pursue careers in medicine, law, or scientific research.

The undergraduate programs in civil engineering and environmental engineering science share a common sophomore year that emphasizes mathematics, mechanics, ecology, and design. The ecology sequence begins by considering how natural systems work and then turns to a consideration of interactions between these systems and human activities. This sequence provides a scientific context for a consideration of sustainable design in subsequent subjects. Sophomore students from all programs work together in teams on design projects that synthesize concepts taught in the core subjects. In the junior and senior years, students from the two programs concentrate on disciplinary subjects that provide depth in each specialty. During the final term of the senior year, all students come together again in an advanced design subject that integrates lessons learned throughout the undergraduate education. There is ample room in the program for electives and minors that can be used to tailor each student’s program to individual needs.

At the graduate level, the department offers two complementary but distinct types of programs. First, research-oriented doctoral and master’s programs advance fundamental understanding and develop innovative approaches to engineering problems. Such programs prepare professionals for positions of leadership in research and teaching. Second, practice-oriented master’s degrees introduce the political, economic, and cultural factors that influence social priorities, and prepare students to function as members of interdisciplinary teams. These programs add technical depth and professional skills beyond the four-year bachelor’s degree.

Graduate programs are offered in the following areas: environmental chemistry and environmental biology; geotechnical and geo-environmental engineering; environmental fluid dynamics, coastal engineering and hydrodynamics; hydrology and water resources; materials and structures; transportation systems and engineering systems (including information technology, transportation, and infrastructure systems).

UNDERGRADUATE STUDY

The Department of Civil and Environmental Engineering offers three undergraduate curricula: Course 1-C, leading to the Bachelor of Science in Civil Engineering, Course 1-E, leading to the Bachelor of Science in Environmental Engineering Science, and Course 1-A, leading to the Bachelor of Science as recommended by the Department of Civil and Environmental Engineering.

Each of these curricula is flexible enough to allow students to pursue special interests by taking subjects in the Department of Civil and Environmental Engineering and in other departments. Undergraduates are encouraged to participate in the research activities of the department and in many cases obtain degree credit for such work.

In general, students find advantages in planning their programs for the third and fourth years so that they dovetail with possible graduate study, including the department’s Master of Engineering degree. This is readily accomplished by those students who embark on the departmental program in their second year. Under certain circumstances, students are permitted to work toward receiving simultaneous undergraduate and graduate degrees.
Bachelor of Science in Civil Engineering/Course 1-C

General Institute Requirements (GIRs)  

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 1.00 or 1.018 and 18.03 in the Departmental Program]</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement [can be satisfied by 1.101 and 1.102 in the Departmental Program]</td>
<td>1</td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td>17</td>
</tr>
</tbody>
</table>

Communication Requirement  
The program includes a Communication Requirement of 4 subjects:  
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and  
2 subjects designated as Communication Intensive in the Major (CI-M)

PLUS Departmental Program  

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Subjects</td>
<td>159</td>
</tr>
<tr>
<td>Core</td>
<td></td>
</tr>
<tr>
<td>1.018</td>
<td>Ecology I: The Earth System, 12; REST; 7.012/7.013/7.014</td>
</tr>
<tr>
<td>1.020</td>
<td>Ecology II: Engineering for Sustainability, 12; CI-M</td>
</tr>
<tr>
<td>1.050</td>
<td>Engineering Mechanics I, 12; 8.01, 18.02</td>
</tr>
<tr>
<td>1.060</td>
<td>Engineering Mechanics II, 12; 1.050, 18.03</td>
</tr>
<tr>
<td>18.03</td>
<td>Differential Equations, 12; REST; 18.02 or 18.04</td>
</tr>
<tr>
<td>1.035</td>
<td>Senior Civil and Environmental Engineering Design, 12, CI-M; permission of instructor</td>
</tr>
<tr>
<td>1.000</td>
<td>Introduction to Computers and Engineering Problem Solving, 12, REST; 18.01</td>
</tr>
<tr>
<td>1.101</td>
<td>Uncertainty in Engineering, 12; 18.02</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td></td>
</tr>
<tr>
<td>1.011</td>
<td>Project Evaluation, 9</td>
</tr>
<tr>
<td>1.035</td>
<td>Mechanics of Structures and Soils, 18; 1.050, 1.060</td>
</tr>
<tr>
<td>1.036</td>
<td>Structural and Geotechnical Engineering Design, 12; 1.035</td>
</tr>
<tr>
<td>1.045</td>
<td>Engineering Systems Design, 12; 1.011</td>
</tr>
<tr>
<td>Laboratory</td>
<td></td>
</tr>
<tr>
<td>1.102</td>
<td>Introduction to Civil &amp; Environmental Engineering Design I, 6, 1/2 LAB; 1.050, 1.018</td>
</tr>
<tr>
<td>1.102</td>
<td>Introduction to Civil &amp; Environmental Engineering Design II, 6, 1/2 LAB; 1.060, 1.020, 1.101</td>
</tr>
<tr>
<td>Restricted Electives</td>
<td>12</td>
</tr>
<tr>
<td>One advanced subject or two advanced half-subjects from the following list:</td>
<td></td>
</tr>
<tr>
<td>1.015</td>
<td>Mechanical Systems, Signal Processing and Stochastics, 12; 18.03</td>
</tr>
<tr>
<td>1.032</td>
<td>Geomaterials and Geomechanics, 12; 1.010, 1.011, 1.035 or equivalent</td>
</tr>
<tr>
<td>1.024</td>
<td>Mechanics of Structures, 12; 1.050 or 2.001, 18.03</td>
</tr>
<tr>
<td>1.045</td>
<td>Mechanics and Design of Concrete Structures, 12; 1.035 or equivalent</td>
</tr>
<tr>
<td>1.124</td>
<td>Foundations of Software Engineering, 12; 1.00</td>
</tr>
<tr>
<td>1.200</td>
<td>Transportation Systems Analysis, 12; permission of instructor</td>
</tr>
<tr>
<td>1.200</td>
<td>Introduction to Transportation Systems, 12; permission of instructor</td>
</tr>
<tr>
<td>1.252</td>
<td>Urban Transportation Planning, 12</td>
</tr>
<tr>
<td>1.260</td>
<td>Logistics Systems, 12</td>
</tr>
<tr>
<td>1.573</td>
<td>Structural Mechanics, 12; 1.052</td>
</tr>
</tbody>
</table>

Departmental Program Units That also Satisfy the GIRs | (36) |

Unrestricted Electives | 48 |

Total Units Beyond the GIRs Required for SB Degree | 183 |

No subject can be counted both as part of the 17-subject GIRs and as part of the 183 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

Bachelor of Science in Civil Engineering/Course 1-C  
The 1-C curriculum helps students develop abilities in problem formulation, problem solving, and decision making in civil engineering. Education towards this goal involves learning fundamentals, exercising creativity, and gaining hands-on experience. Specifically, the program includes subjects dealing with structures, materials, computation, and project evaluation. These are complemented by design subjects that teach students to handle open-ended problems through involvement in increasingly complex team-oriented projects. Unrestricted electives and advanced restricted electives are typically used to build depth in particular areas.

The 1-C program provides the education necessary for professional practice in civil engineering as well as a number of other fields. It also provides a solid foundation for graduate studies and a direct transition to the department’s Master of Engineering program, which is designed to further develop the professional engineering skills of Course 1-C students. This program is ABET accredited.

Bachelor of Science in Environmental Engineering Science/Course 1-E  
The 1-E option is designed for students who wish to gain an in-depth understanding of the physical, chemical, and biological processes that control the natural environment and its interactions with human activities. Subjects in environmental transport and hydrology share a laboratory that emphasizes both hands-on skills and the use of measurements to test hypotheses. The environmental chemistry and biology subject is also accompanied by a laboratory. Concepts learned in these subjects are applied to questions of human health in an advanced upper-class subject. Unrestricted electives and advanced restricted electives are typically used to build depth in particular areas.

The 1-E program provides the education necessary for careers in environmental engineering and science, as well as in many other fields. It also gives a solid foundation for graduate study and research in both basic and applied environmental disciplines. The program is ABET accredited and is sufficiently flexible to prepare students for careers in medicine and environmental law.
Bachelor of Science as recommended by the Department of Civil and Environmental Engineering/Course 1-A

The degree of Bachelor of Science as recommended by the Department of Civil and Environmental Engineering (Course 1-A) is provided for those students who are drawn to the core features of our curriculum but want to design individualized programs to meet particular educational objectives. For example, a student interested in medicine may need more room in the curriculum in order to complete all the subjects required for medical school admission. Other students interested in research careers in fields such as environmental biology, chemistry, or oceanography may want more time for advanced subjects in those fields. Such students may benefit from a Civil and Environmental Engineering 1-A degree, since they do not need ABET accreditation but do need flexibility. Students should speak with a faculty advisor about the advantages and limitations of a 1-A degree before making a final decision.

There are seven required 1-A subjects that coincide with the sophomore core of the 1-C and 1-E programs. In addition, 1-A students must select a coherent set of seven electives that meet a well-defined educational goal (e.g., a premedical sequence). The planned electives are developed in consultation with and are approved by a member of the departmental faculty who serves as the student’s academic advisor. Planned electives may be selected from subjects within the Department of Civil and Environmental Engineering or outside the department. In addition, students may write an undergraduate thesis in lieu of one or more of the planned electives. To satisfy the CI-M component of the Communication Requirement, students must take the department’s two CI-M subjects (1.013 and 1.020) or, if appropriate, take one Course 1 CI-M subject and petition to substitute one CI-M from another science or engineering field. The outside CI-M must fit into the coherent program of electives approved by the student’s academic advisor. The remaining part of the 1-A program consists of unrestricted electives to bring the total to 180 units beyond the General Institute Requirements.

Bachelor of Science in Environmental Engineering Science/Course 1-E

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement(s)</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement [one subject can be satisfied by 1.100, 1.101, 14.01, or 17.32 in the Departmental Program]</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 18.03 and 1.018 in the Departmental Program]</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement [can be satisfied by 1.101 and 1.102 in the Departmental Program]</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The program includes a Communication Requirement of 4 subjects: 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and 2 subjects designated as Communication Intensive in the Major (CI-M).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLUS Departmental Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>Core</td>
<td>168</td>
</tr>
<tr>
<td>1.018</td>
<td></td>
</tr>
<tr>
<td>Ecology I: The Earth System, 12, REST; 7.012/7.013/7.014</td>
<td></td>
</tr>
<tr>
<td>1.020</td>
<td></td>
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<tr>
<td>Ecology II: Engineering for Sustainability, 12, CI-M</td>
<td></td>
</tr>
<tr>
<td>1.050</td>
<td></td>
</tr>
<tr>
<td>Engineering Mechanics I, 12; 8.01, 18.02</td>
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</tr>
<tr>
<td>1.060</td>
<td></td>
</tr>
<tr>
<td>Engineering Mechanics II, 12; 1.050, 18.03</td>
<td></td>
</tr>
<tr>
<td>18.03</td>
<td></td>
</tr>
<tr>
<td>Differential Equations, 12, REST; 18.02 or 18.014</td>
<td></td>
</tr>
<tr>
<td>1.013</td>
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<tr>
<td>Senior Civil and Environmental Engineering Design, 12, CI-M; permission of instructor</td>
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<tr>
<td>One of the following two subjects:</td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Introduction to Computers and Engineering Problem Solving, 12, REST; 18.01</td>
<td></td>
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<tr>
<td>1.010</td>
<td></td>
</tr>
<tr>
<td>Uncertainty in Engineering, 12; 18.02</td>
<td></td>
</tr>
<tr>
<td>1.061</td>
<td></td>
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<tr>
<td>Environmental Engineering Science Transport Processes in the Environment, 12; 1.060, 1.070, 1.106</td>
<td></td>
</tr>
<tr>
<td>1.070</td>
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<tr>
<td>Hydrology, 12; 1.060, 1.061, 1.106</td>
<td></td>
</tr>
<tr>
<td>1.080</td>
<td></td>
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<tr>
<td>Environmental Chemistry and Biology, 12; 1.107, 5.111/5.112/3.092, 7.012/7.013/7.014</td>
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<tr>
<td>1.083</td>
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<tr>
<td>Environmental Health, 12; 1.061, 1.080</td>
<td></td>
</tr>
<tr>
<td>1.106</td>
<td></td>
</tr>
<tr>
<td>Environmental Transport and Hydrology/Laboratory, 6, 1/2 LAB; 1.061, 1.070</td>
<td></td>
</tr>
<tr>
<td>1.107</td>
<td></td>
</tr>
<tr>
<td>Environmental Chemistry and Biology Laboratory, 6, 1/2 LAB; 1.080</td>
<td></td>
</tr>
<tr>
<td>Economics and Public Policy</td>
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<tr>
<td>One of the following four subjects:</td>
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<tr>
<td>11.002</td>
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<tr>
<td>Fundamentals of Public Policy, 12; HASS-D, CI-H</td>
<td></td>
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<tr>
<td>11.122</td>
<td></td>
</tr>
<tr>
<td>Society and Environment, 12; HASS</td>
<td></td>
</tr>
<tr>
<td>14.01</td>
<td></td>
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<tr>
<td>Principles of Microeconomics, 12; HASS</td>
<td></td>
</tr>
<tr>
<td>17.32</td>
<td></td>
</tr>
<tr>
<td>Environmental Politics and Policy, 12; HASS-D, CI-H</td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td></td>
</tr>
<tr>
<td>1.101</td>
<td></td>
</tr>
<tr>
<td>Introduction to Civil &amp; Environmental Engineering Design I, 6, 1/2 LAB; 1.050, 1.018</td>
<td></td>
</tr>
<tr>
<td>1.102</td>
<td></td>
</tr>
<tr>
<td>Introduction to Civil &amp; Environmental Engineering Design II, 6, 1/2 LAB; 1.101, 1.060, 1.020</td>
<td></td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Restricted Elective</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>One advanced subject from the following list:</td>
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</tr>
<tr>
<td>1.071</td>
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<tr>
<td>Global Change Science, 12; 18.03, 5.60</td>
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<tr>
<td>1.64</td>
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<tr>
<td>Physical Limnology, 12; 1.061</td>
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<tr>
<td>1.69</td>
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<tr>
<td>Introduction to Coastal Engineering, 12; 1.061</td>
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<td>1.70</td>
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<tr>
<td>Groundwater Hydrology, 12; 1.061</td>
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<tr>
<td>1.731</td>
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<tr>
<td>Water Resources Systems, 12; 1.070</td>
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<td>1.77</td>
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<tr>
<td>Water Quality Control, 12; 1.060</td>
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<tr>
<td>1.83</td>
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<tr>
<td>Environmental Organic Chemistry, 12; 5.12, 5.60</td>
<td></td>
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<tr>
<td>1.89</td>
<td></td>
</tr>
<tr>
<td>Environmental Microbiology, 12; 7.014</td>
<td></td>
</tr>
</tbody>
</table>

| Departmental Program Units that also Satisfy the GIRs | (48) |
| Unrestricted Electives | 48 |

<table>
<thead>
<tr>
<th>Total Units Beyond the GIRs Required for SB Degree</th>
<th>180</th>
</tr>
</thead>
</table>

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

Notes

(1) Any of the subjects that fulfill the Institute Chemistry Requirement is satisfactory, though 5.111 or 5.112 is recommended.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
Bachelor of Science as Recommended by the Department of Civil and Environmental Engineering/Course 1-A

General Institute Requirements (GIRs)  Subjects
Science Requirement  6  
Humanities, Arts, and Social Sciences Requirement  8  
Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 1.018 and 18.03 in the Departmental Program]  2  
Laboratory Requirement [can be satisfied by 1.101 and 1.102 in the Departmental Program]  1  
Total GIR Subjects Required for SB Degree  17  

Communication Requirement  
The program includes a Communication Requirement of 4 subjects: 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and 2 subjects designated as Communication Intensive in the Major (CI-M).  
PLUS Departmental Program  Units  
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics).  
Required Subjects  84  
Core  
1.018 Ecology I: The Earth System, 12, REST; 7.012/7.013/7.014  
1.020 Ecology II: Engineering for Sustainability, 12, CI-M  
1.060 Engineering Mechanics I, 12; 8.01, 18.02  
1.061 Engineering Mechanics II, 12; 1.050, 18.03  
18.03 Differential Equations, 12, REST; 18.02 or 18.014  
One of the following two subjects:  
1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; 18.01  
1.020 Uncertainty in Engineering, 12; 18.02  
Laboratory  
1.101 Introduction to Civil and Environmental Engineering Design I, 6, 1/2 LAB; 1.050, 1.018  
1.102 Introduction to Civil and Environmental Engineering Design II, 6, 1/2 LAB; 1.101, 1.060, 1.020  
Restricted Electives  84  
Students are required to take a coherent set of seven full subjects that meet a well-defined educational goal. These may be from within or outside the Department of Civil and Environmental Engineering. The electives must be approved by the student’s academic advisor and the undergraduate officer of the department.  
Departmental Program Units That also Satisfy the GIRs (36)  
Unrestricted Electives  48  
Total Units Beyond the GIRs Required for SB Degree  180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

Notes  
(1) To satisfy the CI-M component of the Communication Requirement, students must take the department’s two CI-M subjects (1.013 and 1.020) or, if appropriate, take one Course 1 CI-M subject and petition to substitute one CI-M from another science or engineering field. The outside CI-M must fit into the coherent program of electives approved by the student’s academic advisor. 
For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

Undergraduate Summer Internship Program  
Sophomores and juniors majoring in civil and environmental engineering may apply to participate in the Undergraduate Summer Internship Program, coordinated by the Department of Civil and Environmental Engineering. The internship program helps students find summer employment opportunities in civil and environmental engineering. The department works with many companies and agencies to ensure that attractive internship opportunities are available for qualified students. For more information and a partial listing of companies, see the Summer Internship Program description on the departmental website at http://cee.mit.edu/.

Undergraduate Practice Opportunities Program  
The Undergraduate Practice Opportunities Program (UPOP) is a new program sponsored by the School of Engineering and administered through the Office of the Dean of Engineering. Further information on the program may be obtained from the department in which the student is registered or from Christopher Resto, Director, Undergraduate Practice Opportunities Program, MIT, Room 12-188, Cambridge, MA 02139-4307, 617-452-5099, fax 617-253-8457, cresto@mit.edu, or from http://web.mit.edu/engineering/upop/.

Electives and Research Opportunities  
A list of undergraduate electives in civil and environmental engineering may be obtained from the department. Students registered in the department are encouraged to consider appropriate subjects offered by other departments as part of their elective programs. Students wishing to work closely with a member of the faculty on research may obtain permission to register for thesis, or to enroll in 1.999 Undergraduate Studies in Civil and Environmental Engineering. Numerous possibilities for UROP projects exist in the department, and several UROP traineeships are awarded to undergraduates each spring.
Minor Programs

The Minor in Civil Engineering consists of the following subjects:

- 1.050 Engineering Mechanics I
- 1.060 Engineering Mechanics II
- 1.101 Introduction to Civil and Environmental Engineering Design I
- 1.102 Introduction to Civil and Environmental Engineering Design II
- 1.035 Mechanics of Structures and Soils
- 1.041 Engineering Systems Design
- 1.036 Structural and Geotechnical Engineering Design

The Minor in Environmental Engineering Science consists of the following subjects:

- 1.018 Ecology I: The Earth System
- 1.020 Ecology II: Engineering for Sustainability
- 1.101 Introduction to Civil and Environmental Engineering Design I
- 1.102 Introduction to Civil and Environmental Engineering Design II
- 1.080 Environmental Chemistry and Biology
- 1.107 Environmental Chemistry and Biology Laboratory

Substitution of equivalent subjects offered by other departments is allowed, with permission of the minor advisor. However, at least three subjects must be Course 1 subjects.

For a general description of the minor program, see Undergraduate Education in Part 1.

Graduate Study

The Department of Civil and Environmental Engineering grants the following advanced degrees: Master of Engineering in Civil and Environmental Engineering, Master of Science in Civil and Environmental Engineering, Civil Engineer, Doctor of Science, and Doctor of Philosophy. The Institute’s general requirements for these degrees are described under Graduate Education in Part 1. Detailed information on the departmental requirements for each degree may be obtained from the Academic Programs Office, Room 1-281.

Master of Engineering in Civil and Environmental Engineering

The department introduced the Master of Engineering (MEng) degree in 1995 as an important new complement to the department’s ongoing Master of Science in Civil and Environmental Engineering and doctoral degrees. The program of study is designed for individuals with a bachelor’s degree in engineering or a closely related field, and provides additional technical depth and an educational experience geared to professional practice.

The MEng is a fast-paced, intensive program designed to be completed in nine months. It is organized as follows:

All students, independent of specialty area, take 1.133 Concepts of Engineering Practice, during the fall term. In this subject, participants work in teams to develop and present solutions to realistic professional problems, including topics such as project management and evaluation, negotiation, business development, and ethics.

In addition, each specialty area has three suggested core subjects, two planned electives, and one free elective.

The distinctive element of the program is a professional practice experience for each specialty area. It is composed of a required group project leading to an individual, practice-oriented thesis that builds on the group project.

Because of their intensive coursework, MEng students do not have time to work as full-time research or teaching assistants. Some engage in part-time work, but we urge caution as this can drain time away from academic work. A limited number of partial-tuition fellowships are awarded on a merit basis.

Admission standards are the same as for the Master of Science degree. MIT undergraduates may apply to the program at the end of their third year. Strong communication skills are expected.

For more information, see the Master of Engineering program description on the department’s website at http://cee.mit.edu/.

Fields of Advanced Study

Programs of advanced study are available in the following areas: geotechnical and geo-environmental engineering, structures and materials, environmental fluid mechanics and coastal engineering, hydrology, aquatic sciences, and systems (including transportation and information technology).

Geotechnical engineering emphasizes fundamental principles of mechanics, materials, engineering geology, computational analysis and analysis of uncertainty that lay the basis for dealing with the challenging geotechnical engineering problems of the future.

Geo-environmental engineering expands this emphasis to include contaminants in soils, in situ investigations, and remediation concepts building on geotechnical expertise and on other well-developed environmental activities in the department in fields such as chemistry and groundwater hydrology.

The major areas of research are soft-ground construction, underground construction, constitutive modeling, fundamentals of material behavior, stability of natural rock slopes, pile foundations, applications of probability and decision theory, in situ testing, mining geotechnics, contaminant transport, earthquake engineering, and centrifuge model testing.

Structure and materials gives students a broad understanding of the behavior of structures and the materials from which they are made. In the academic program, emphasis is placed on structural mechanics, mechanical behavior of construction materials, and the design of structural systems. Additional subjects in numerical methods and condition assessment in engineering are also recommended.

The current research program includes projects on computer-aided structural engineering, intelligent structural engineering systems, and high-performance bridges using innovative concepts. Additional projects include soil-structure interaction under seismic load, structural assessment, retrofit of damaged concrete and fracture critical steel structures using FRP composites, high-performance cementitious materials, including silica fume concrete and
Research opportunities encompass laboratory, field, and modeling studies with an emphasis on the fate and transport of pollutants, chemical and microbial transformations, biological oceanography, plankton ecology, molecular ecology, wetland geochemistry, harbor and coastal modeling, and local and regional water quality.

Students in the systems doctoral program conduct scholarly research by applying computational, operations research, and statistical methods to civil and environmental engineering applications such as infrastructure, transportation, logistics, environment, energy, and security. Every PhD student will acquire proficiency in each of the three dimensions: information technology, modeling and analysis, and civil and environmental engineering applications. The exact mix is determined by the student and her/his doctoral dissertation committee, depending on the student’s interests. Program faculty are drawn from the areas of information technology, transportation, and logistics.

Entrance Requirements for Graduate Study
Applicants do not need to have an undergraduate degree in civil engineering.

Numerous opportunities for graduate education in civil and environmental engineering exist for students with backgrounds in other branches of engineering, science, and certain social sciences. These arise through the growth of interdepartmental research and degree programs that bring people of diverse backgrounds together in search of solutions to major societal problems. Graduate students and faculty in the department have experience, for example, in economics, political science, sociology, architecture, urban and regional planning, management, biology, geology, chemistry, computer science, and oceanography.

Primary requirements for graduate study are a keen intellect combined with capability and interest in rigorous approaches to real problems. Students may make up deficiencies in prerequisites while pursuing a program of graduate study. Prerequisites for each subject are given in the subject descriptions. All applicants are required to submit scores from the GRE Aptitude Test.

Financial Assistance
The research of the department is an integral part of the graduate program, and approximately 135 graduate students each year receive appointments as research or teaching assistants. Most of these appointments fully cover tuition, individual health insurance, and reasonable living expenses in the Boston area.

The Department of Civil and Environmental Engineering also has a number of fellowships for first-year graduate students. Applicants are also encouraged to apply for traineeships and fellowships offered nationally by the National Science Foundation, NASA, DOE, and other governmental agencies that traditionally support students in the department. For an extensive list of such opportunities, visit the Graduate Students Office website, http://web.mit.edu/gso/.

Interdepartmental Programs
Through its interdepartmental programs, the Civil and Environmental Engineering Department brings together the science, technology, systems, and management skills necessary to deal with the important engineering problems of the future.

Master of Science in Transportation
The educational and research programs in transportation center around the interdepartmental Master of Science in Transportation (MST) program. This program is based on the premise that a common set of analytical approaches and methodologies can be applied to solve a range of transportation problems. The MST provides a common basis for addressing a wide range of problems while allowing enough flexibility to accommodate students with diverse backgrounds and interests.

The only specific subjects required for admission are two subjects in calculus, one in economics, and one in probability. One or more of these subjects may be completed simultaneously with application to the program, and acceptance is then conditional on satisfactory completion of these prerequisites.

The MST typically takes one and one-half to two years to complete. Students in the MST program must complete a block of three required core subjects and three additional transportation or related subjects, in addition to the master’s thesis. Generally, the three additional subjects are complemen...
subjects relate to an area of specialization, although this is not required. Common areas of specialization include urban transportation, air transportation, planning methods, logistics, policy, and ocean systems management.

For more information, see the MST program description on the department’s website at [http://cee.mit.edu/](http://cee.mit.edu/).

**Leaders for Manufacturing Program**

The Leaders for Manufacturing (LFM) program combines graduate education in engineering and management for those with two or more years of work experience who aspire to leadership positions in manufacturing or operations companies. This rigorous 24-month program combines subjects in technology and management. A required 6.5-month internship provides opportunity to complete a research project on site at one of LFM’s partner companies. The internship leads to a dual-degree thesis, culminating in two master’s degrees—an SM in management or an MBA, and an SM in engineering from the Department of Civil and Environmental Engineering. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description in the Engineering Systems Division section in Part 2 or visit [http://lfm.mit.edu/](http://lfm.mit.edu/).

**Joint Program with the Woods Hole Oceanographic Institution**

The Joint Program with the Woods Hole Oceanographic Institution is intended for students whose primary career objectives are in the field of oceanography or oceanographic engineering. The program is described in the section on Interdisciplinary Graduate Programs in Part 2.

**Research Laboratories and Activities**

The Department of Civil and Environmental Engineering occupies two major facilities on the MIT campus: the Ralph M. Parsons Laboratory and the Henry L. Pierce Engineering Laboratory. These buildings contain specialized research and teaching facilities, described below.

**Ralph M. Parsons Laboratory**

Located on the east campus, the Ralph M. Parsons Laboratory is a recently renovated four-story structure containing about 31,000 square feet of classrooms, teaching and research laboratories, machine shops, computer facilities, and offices. Approximately 70 graduate students and 17 faculty members have offices on the premises. Facilities exist for hydrodynamic studies involving wave motions, free surface flows, and flows in porous media. The latest in laser-Doppler instrumentation is available. Complete and modern laboratories facilitate research in inorganic chemistry, organic chemistry, biology, microbiology, and biochemistry. Especially notable instrumentation includes several GCs, a GC-MS, several HPLCs, an ICP, a graphite furnace AA, alpha and gamma spectrometry counting systems, scintillation counters, several flow cytometers, a laser light scattering instrument, and incubators, a cold room, and a clean room. Two laboratories are dedicated teaching facilities for environmental engineering and aquatic chemistry. Equipment is available for instruction in a wide range of field sampling methods, biological and microbiological evaluations, and instrumental chemical analyses of natural waters. Computer facilities include an 80-processor Beowulf (parallel computing) cluster.

**Henry L. Pierce Engineering Laboratory**

Located in one of MIT’s original buildings, this facility overlooks the Charles River and includes over 40,000 square feet of classrooms, teaching and research laboratories, and offices for approximately 200 graduate students and 21 faculty members and research staff from five professional programs: materials and structures, transportation, information technology, geoenvironment and geotechnology, and construction engineering and management.

Research activities focus on four major areas: infrastructure, geoenvironment, information and management, and transportation. Among the classrooms is the state-of-the-art Bechtel Lecture Hall. Facilities include an undergraduate structures teaching laboratory, and a materials testing laboratory which provides facilities to process, fabricate and form specimens, test under various stress and environmental conditions, and investigate physical properties. The materials testing laboratory contains several servo hydraulic load frames, a biaxial loading system, and an environmental chamber. A scanning electron microscope with an X-ray analyzer is also available for microstructural characterization and chemical analysis of materials. The geotechnical laboratories combine a broad range of equipment from conventional state-of-the-art to specialty research devices. Capabilities include industrial radiography; low-temperature room; centralized data acquisition; computer-automated consolidation, triaxial and simple shear devices; and a medium-sized centrifuge. The nondestructive evaluation (NDE) laboratory is equipped with an ultrasonic scanning and imaging system, an ultrasonic phased array system, and a high-power Nd:YAG laser system. The laboratory also houses a large variety of transducers and NDE facilities for transducer manufacturing and calibration, design and fabrication of control electronic circuitry, acoustic emission, and magnetic particle testing.

The Pierce Laboratory offers diverse and advanced computational facilities, including a large Athena cluster; networked Sun, Digital, SONY, and Windows NT workstations; and numerous personal computers. Software features
the X Window System, Motif, and C++ application environments and includes various AI programming tools, CAD packages, and multimedia hardware and software.

Laboratory for Energy and the Environment
The Education Program of the Laboratory for Energy and the Environment (LCEE) is dedicated to enhancing environmental literacy and deepening multidisciplinary environmental knowledge, particularly among the leaders of tomorrow’s science and technology communities. The program cultivates the capacity of learners at all levels to both understand and respond effectively to the challenges of sustainability. More information about LCEE is available under Interdisciplinary Research and Study in Part 1.

Center for Environmental Health Sciences
Historically, the Department of Civil and Environmental Engineering has had strong ties to the Center for Environmental Health Sciences in teaching and research activities related to understanding the role of chemical and biological agents in the environment as causes of human disease. More information about the center is available under Interdisciplinary Research and Study in Part 1.

Earth Systems Initiative
The Earth Systems Initiative (ESI) seeks to understand the intimate relationships among the physical, chemical, biological, and geological processes that shape the Earth system. By involving faculty, staff, and students from a variety of environmentally oriented disciplines, ESI leverages different perspectives, and systems-oriented approaches, so that we can better understand how our planet functions, and how humans can be effective stewards of the Earth. For more information, see Interdisciplinary Research and Study in Part 1.

Center for Global Change Science
The Center for Global Change Science (CGCS) seeks to understand the processes, natural and human-induced, that lead to changes in the atmosphere, oceans, and continental land masses. This interdepartmental center provides the opportunity for close cooperation in education and research between faculty and students of the Department of Civil and Environmental Engineering, the Department of Earth, Atmospheric, and Planetary Sciences, and other MIT departments. Major CGCS projects include the Climate Modelling Initiative, the Joint Program on the Science and Policy of Global Change, and the Advanced Global Atmospheric Gases Experiment. More information about the center is in Part 1: Interdisciplinary Research and Study.

Mining and Mineral Resources Research Institute
The Mining and Mineral Resources Research Institute coordinates academic and research activities in the mineral resources field.

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Jingfeng Wang, PhD

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Professor of Civil and Environmental Engineering, Emeritus
Robert Van Duyne Whitman, ScD
Professor of Civil and Environmental Engineering, Emeritus
Many of the products and services in modern society are based upon the work of electrical engineers and computer scientists.

The tremendous increase over the last decade in the capabilities of digital electronic devices has led to an explosive growth in the use of computers and computation. At the same time, our increased understanding of computer science has made possible the development of new software systems of increased power, sophistication, and flexibility.

Electrical communication systems involving wires, optical fibers, or wireless technology abound in radio, television, telephone, and computer communication networks. Modern electronics has made possible sophisticated instrumentation systems for use in all branches of the physical and biological sciences, as well as in most areas of engineering and manufacturing. Electrical machines and electronic circuits control a multitude of systems that deeply affect our lives in many ways. The large quantities of electric power that serve society are provided by electric generators and are controlled and distributed by complex transmission and switching networks.

Modern electronic systems are increasingly digital in nature, exceedingly complex, and would be inconceivable without today’s VLSI chip technology. Indeed, such systems are so complex that the principles of their design bear great similarities to the design principles of large software systems. Thus, computer science and electronic system design require similar backgrounds in many respects, and computer aids to design are essential in this ever-expanding domain of engineering.

The pervasiveness and success of electrical engineering and computer science are due in large part to the conceptual models that electrical engineers and computer scientists have developed for the devices and systems with which they work. These models are based on a background of mathematics and physical sciences, including the fundamental electric and magnetic properties of materials, and are employed in a wide range of applied problems in both man-made and biological systems.

Accordingly, the focus of the undergraduate curricula is on the fundamental principles and models of the electrical and computer sciences. Engineering concentrations, laboratory subjects, independent projects, and research complement this preparation by introducing more specialized techniques of analysis, design, and experimentation in a variety of fields.

More information about the Department of Electrical Engineering and Computer Science and its programs can be obtained from the department’s website at http://www-eecs.mit.edu/.

PROFESSIONAL AND PREPROFESSIONAL PROGRAMS

For students entering MIT from secondary schools and planning professional careers in the fields of electrical engineering and computer science, the Department of Electrical Engineering and Computer Science offers programs leading to the Master of Engineering degree and to the Bachelor of Science degree. Three preprofessional four-year bachelor’s programs are available. One is for students specializing in electrical science and engineering, a second for those specializing in computer science and engineering, and a third for those whose interests cross this traditional boundary. For qualified students, the principal departmental professional program leads directly, through a seamless five-year course of study, to the simultaneous awarding of the Master of Engineering and one of the three bachelor’s degrees. An undergraduate who wishes to pursue the Master of Engineering degree should initially register for any of the three bachelor’s programs. The 6-A Internship Program combines either the professional Master of Engineering or a preprofessional bachelor’s academic program with periods of industrial practice at affiliated companies. All these programs are described in more detail in the paragraphs and sections that follow. A Minor in Biomedical Engineering is also available. For more information, see the School of Engineering Overview.

The program leading to the Master of Engineering degree in Electrical Engineering and Computer Science is intended to provide the depth of knowledge and the skills needed for professional work as well as the breadth and perspective essential for engineering leadership in an increasingly complex technological world. This program builds on the General Institute Requirements in science and the humanities, together with 18.03 Differential Equations and the core of required departmental subjects (6.001, 6.002, 6.003, and 6.004, each including a laboratory component), which introduce students to the fundamentals of electrical circuits, signals and dynamic systems, the principles of computation, and the organization of computing systems. The heart of the program is a group of nine Engineering Concentration subjects selected from seven concentration lists under constraints designed to ensure appropriate depth and breadth. The remainder of the program consists of restricted choices in engineering laboratories and mathematics which, together with free electives and a thesis, permit individual students to shape their programs to their special interests.

The major part of the Master of Engineering curriculum is composed of classroom subjects presented in lecture-recitation format. These subjects provide an organized introduction to the principles and applications of electrical engineering and computer science—an introduction that is reinforced by regularly assigned homework exercises and, in many cases, elementary laboratory or design problems. An appreciation of the principles of successful design is an important goal of the curriculum. The extent to which each departmental subject contributes towards this goal is indicated in the catalogue description of the subject through the specification of Engineering Design (ED) points; a total of at least 48 ED points is required in each student’s program.

The focus on design is also aided by two other important components of the Master of Engineering program: laboratory-project subjects and thesis. Laboratory-project subjects expose the student to the design of experiments, equipment, or computer programs, as well as to the problems of implementation and the evaluation of results. Because of the importance of this experience, students are expected to complete one departmental laboratory subject in addition to the General Institute Laboratory Requirement, which may be satisfied by a second departmental laboratory subject. Most departmental laboratory subjects provide 12 ED points. The thesis for the Master of Engineering degree is normally 24 units of effort; each thesis is assigned an appropriate number of ED points by the thesis supervisor depending on the nature of the activity.
Joint theses, based on a group project in which each participant has an identified responsibility, are encouraged.

The four-year preprofessional programs leading to a Bachelor of Science degree are shorter and less comprehensive than the Master of Engineering program. These programs are accredited by the Accreditation Board for Engineering and Technology (ABET) and, in the case of 6-2 and 6-3, by the Computing Accreditation Commission of ABET (CAC). Recipients of a Master of Engineering degree normally receive a Bachelor of Science degree simultaneously. No thesis is explicitly required for the preprofessional Bachelor of Science degree. However, every program must include a major project experience at an advanced level, culminating in written and oral reports. Normally, the thesis for the Master of Engineering degree provides this experience for students receiving both degrees simultaneously.

The requirements listed for the department programs are not rigid. Much flexibility is built into the elective structure; 48 units of totally unrestricted electives are included in every Master of Engineering program. Some further variations in requirements are routinely permitted, while still others will be considered on an individual basis. Approval of requests for substantial changes may be granted to well-prepared students whose proposed programs provide an integrated approach to a well-defined educational objective and are comparable with the listed curricula in breadth and depth. Changes affecting the required core portion of each curriculum, however, are rarely approved.

Programs leading to the professional five-year Master of Engineering degree or the preprofessional four-year Bachelor of Science degrees can easily be arranged to be identical through the junior year. At the end of the junior year, students with strong academic records will be offered the opportunity to continue through the five-year master’s program. To remain in the program and to receive the Master of Engineering degree, students will be expected to maintain strong academic records. Admission to the Master of Engineering program is open only to undergraduate students who have completed their junior year in the Department of Electrical Engineering and Computer Science at MIT. Students with other preparations seeking a master’s level experience in EECS at MIT should

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### Bachelor of Science in Electrical Science and Engineering, Course 6-1
### Bachelor of Science in Electrical Engineering and Computer Science, Course 6-2
### Bachelor of Science in Computer Science and Engineering, Course 6-3

Those receiving simultaneous award of Master of Engineering in Electrical Engineering and Computer Science/Course 6-P: See Course description of 6-P.

#### General Institute Requirements (GIRs)

<table>
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<tr>
<th>Requirement</th>
<th>Subjects</th>
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<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>[can be satisfied by 6.001 or 6.002, and 18.03 in the Departmental Program]</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total GIR Subjects Required for SB Degree**

**17**

#### Communication Requirement

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

#### PLUS Departmental Program Requirements

<table>
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<th>Units</th>
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<td><strong>84</strong></td>
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</table>

**Required Subjects**

- **6.001** Structure and Interpretation of Computer Programs, 15 (ED 4), REST
- **6.002** Circuits and Electronics, 15 (ED 4), REST; 18.02*, 18.03*
- **6.003** Signals and Systems, 15 (ED 4); 6.002
- **6.004** Computation Structures, 15 (ED 4); 6.001, 6.002
- **18.03** Differential Equations, 22, REST; 18.02* or 18.014
- **6.101/6.102** Undergraduate Advanced Project, 12 (ED 0-12)

**Restricted Electives**

- **84**
  1. Either 6.043 (alternatively 18.440) or 6.042.
  2. One 12-unit subject selected from the undergraduate laboratory subjects 6.100–6.182. Students in Course 6-3 must select 6.170. 6-1 and 6-2 students who take both 6.021 J and 6.022 J may use 6.022 J to satisfy the department laboratory requirement. Note that both the department laboratory requirement and the General Institute Laboratory Requirement.
  3. Five subjects from the list of Engineering Concentration subjects constrained as follows:
     a) Students in Course 6-1 must take the header subjects in any three of the four Electrical Engineering Concentrations (Bioelectrical Engineering; Communication, Control, and Signal Processing; Devices, Circuits, and Systems; and Electrodynamics and Energy Systems). They must also take one additional subject in one of the three chosen Concentrations and one additional subject from any of the seven Concentrations.
     b) Students in Course 6-3 must take the header subjects in each of the three Computer Science Concentrations (Artificial Intelligence and Applications; Computer Systems and Architecture; Theoretical Computer Science). They must also take one additional subject in one of these three Concentrations and one additional subject from any of the seven Concentrations.
     c) Students in Course 6-2 must take the header subjects from any two of the four Electrical Engineering Concentrations and any two of the three Computer Science Concentrations.

#### Departmental Program Units That also Satisfy the GIRs

**27**

**Unrestricted Electives**

**48**

**Total Units Beyond the GIRs Required for SB Degree**

**189**

No subject can be counted both as part of the 17-subject GIRs and as part of the 189 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both. No subject may be counted in more than one of the three departmental restricted elective categories.

**Notes**

*Alternate prerequisites are listed in the subject descriptions.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
see the Master of Science program described later in this section.

The fifth year of study toward the Master of Engineering degree can be supported by a combination of personal funds, participation in the 6-A Internship Program described later in this section, an award such as a National Science Foundation Fellowship, a fellowship or a graduate assistantship, or an interest-subsidized student loan. Assistantships require participation in research or teaching in the department or in one of the associated laboratories. Assistants normally register for two scheduled classroom or laboratory subjects, and may receive academic credit for their participation in the teaching or research program. Support through an assistantship may extend the period required to complete the Master of Engineering program by an additional term or two. Support is granted competitively to graduate students and will not be available for all of those admitted to the Master of Engineering program. If provided, department support for Master of Engineering candidates is limited to the first three terms as a graduate student, unless the Master of Engineering thesis has been completed or the student has been admitted to the doctoral program, in which case a 4th term of support may be permitted.

Additional information about the department’s professional and preprofessional programs may be obtained from the EECS Undergraduate Office, Room 38-476, MIT, 617-253-7329, ug@eecs.mit.edu.

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### Master of Engineering in Electrical Engineering and Computer Science/Course 6-P

**See Notes on Bachelor’s Degree Programs**

#### General Institute Requirements (GIRs)

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</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total GIR Subjects Required for SB and MEng Degrees**

| 17 |

#### Communication Requirement

The program includes a Communication Requirement of 4 subjects: 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and 2 subjects designated as Communication Intensive in the Major (CI-M).

#### PLUS Departmental Program

Subject names below are followed by credit units, Engineering Design (ED) points, and by prerequisites (if any (corequisites in italics).

**Required Subjects**

<table>
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<td>108</td>
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- 6.001 Structure and Interpretation of Computer Programs, 15 (ED 4), REST
- 6.002 Circuits and Electronics, 15 (ED 4), REST; 8.01*, 18.03*
- 6.003 Signals and Systems, 15 (ED 4); 6.002
- 6.004 Computation Structures, 15 (ED 4); 6.001, 6.002
- 18.03 Differential Equations, 12, REST; 18.02* or 18.014
- 6.UAT/6.UAP Undergraduate Advanced Project, 12 (ED 0-12)
- 6.ThM MEng Program Thesis, 24 (ED 0-24)(i)

#### Restricted Electives

1. Three of the following Mathematics subjects including 6.041 (alternatively 18.440) or 6.042 of both. Note that some of these subjects are prerequisites for several subjects in the Engineering Concentration lists and are required in certain designated SB programs.

- 6.041 Probabilistic Systems Analysis, 12, REST; 18.02
- (or 18.440 Probability and Random Variables, 12; 18.03)
- 6.042 Mathematics for Computer Science, 12; 18.01
- 18.04 Complex Variables with Applications, 12; 18.03
- (or 18.075 Advanced Calculus for Engineers, 12; 18.05)
- 18.06 Linear Algebra, 12; REST; 18.02
- (or 18.030 Linear Algebra, 12; REST; 18.02)
- 18.085 Mathematical Methods for Engineers I, 12; 18.03*
- 18.086 Mathematical Methods for Engineers II, 12; 18.03*
- 18.089 Mathematical Methods for Engineers III, 12; 18.03*
- 18.312 Principles of Applied Mathematics, 22; 18.03*
- 18.330 Introduction to Numerical Analysis, 12; 18.03*
- 18.353 Nonlinear Dynamics I: Chaos, 12; 18.03, 18.02
- 18.303 Modern Algebra, 12; 18.02
- 18.701 Theory of Numbers, 12

2. One 12-unit subject selected from the undergraduate laboratory subjects 6.100–6.182. 6-1 and 6-2 students who take both 6.021J and 6.022J may use 6.022J to satisfy the department laboratory requirement. Note that this departmental requirement is in addition to the General Institute Laboratory Requirement.

3. A total of nine subjects from the lists of Engineering Concentrations, as follows: (a) a Large Concentration consisting of a header and two other subjects from a single Engineering Concentration; (b) two Small Concentrations, each consisting of a header and one other subject from a single Engineering Concentration; (c) two additional Concentration Elective Subjects, freely chosen from any of the seven Engineering Concentrations. Note that prerequisite structures and designated SB program requirements may place further constraints on these selections.

- Every approved degree program must include 66 units of graduate credit in addition to the 24 units of 6.ThM (MEng Thesis) listed above. The 66 units of graduate credit must include four H-level subjects totaling at least 42 units; these 42 units must include 36 units of H-level subjects taken within the department.

- To complete the required Communication-Intensive Subjects in the major, students must take one of the CI-M subjects as a restricted elective in categories 2 or 3 above by the end of the third year.


- Every approved degree program must be arranged so as to satisfy the requirements of one of the three bachelor’s degree programs.
Engineering Concentrations

Artificial Intelligence and Applications
This concentration is concerned with the use of computation to accomplish specific tasks that are complex and often only weakly defined. Attention necessarily focuses on subsets of these tasks for which useful solutions can be developed. Since problems in this area are often motivated by a desire to understand or emulate intelligent human behavior, there are strong links to other fields such as neuroscience, psychology, mechanical engineering, and linguistics.

6.034 Artificial Intelligence

Undergraduate

Graduate H- and G-level

*No longer offered, but may be used if taken in previous years.

Bioelectrical Engineering
This concentration applies engineering principles and tools to the understanding of living systems and to the design of technical devices whose specifications require some knowledge of the properties of living systems. Examples include the quantitative description of biological, physiological, or psychological systems, e.g., circulatory, sensory, or skeletal systems, protein or genetic structures, speech and natural language; devices that improve the operation of pathological systems, e.g., pacemakers, sensory aids, artificial tissues; and systems that aid in the effective delivery of health care, e.g., imaging systems, medical decision aids.

6.021J Quantitative Physiology: Cells and Tissues

Undergraduate

Graduate H-level

Appropriate graduate H-level Course 7, Course 9, BE, and HST subjects.

*No longer offered, but may be used if taken in previous years.

Communication, Control, and Signal Processing
This concentration is concerned with fundamental issues in the design, modeling, identification, optimization, and control of stochastic and/or dynamic systems; and the analysis and synthesis of algorithms and systems that process signals or information. Related applications are of interest, such as optical and data communication networks; processing of speech, image, radar, geophysical, oceanographic, and other signals; distributed and parallel computation; neural networks; power systems; aerospace systems; and logistical systems.

6.011 Introduction to Communication, Control, and Signal Processing

Undergraduate
6.401*, 16.36

Graduate H-level

*No longer offered, but may be used if taken in previous years.

Computer Systems and Architecture
This concentration is characterized by its emphasis on the artifacts underlying computing systems, such as machine architectures, networks, data management systems, and compilers. The problems studied are typically relatively well defined, and solutions are evaluated according to many criteria, including performance, cost, and completeness. Many subjects emphasize design and optimization issues and the definition of interfaces.

6.033 Computer System Engineering

Undergraduate
6.035, 6.805

Graduate H-level

*No longer offered, but may be used if taken in previous years.
**Devices, Circuits and Systems**

This concentration concerns the application of electronics to the tasks of signal processing and energy transduction, including synthesis and fabrication as well as analysis and modeling of components, networks, and systems. Examples include digital and analog circuits and systems; power electronics, D/A and A/D conversion; silicon and compound semiconductor physics, devices and simulation; microelectromechanical sensors and actuators; quantum physics and devices; superconductivity.

6.012 Microelectronic Devices and Circuits

**Theoretical Computer Science**

This concentration is characterized by the use of mathematics to better understand computation. The subarea of complexity theory studies the limits and capabilities of various models of computation, as well as the relationships among models. In the subarea of algorithms, the efficient use of computational resources—such as time, memory, and the number of processors—is explored. The subarea of semantics studies the expressiveness of computer languages. Topics within theoretical computer science are drawn from the entire range of computer science, from artificial intelligence to systems engineering, but with an emphasis on formal reasoning.

6.041* Introduction to Algorithms

**Electrodynamics and Energy Systems**

This concentration concerns the applications of Maxwell’s equations and the Lorentz force law to quasistatic and electrodynamic systems and media. Examples include power systems; rotating machinery; electromechanical actuators, sensors, and systems; dielectric physics and high-voltage engineering; electromagnetic wave theory; radio, microwave, and optical systems; electrodynamics of plasmas and fusion energy systems; lasers, nonlinear optical interactions, and optical information processing; and electrophysiological and electrochemical systems.

6.013 Electromagnetics and Applications

**6-A Internship Program**

The 6-A Internship Program enables students to combine classroom studies with practical experience in industry through a series of supervised work assignments at one of the companies or laboratories participating in the program. Collectively, the participating organizations provide a wide spectrum of assignments in the various fields of electrical engineering and computer science, as well as an exposure to the kinds of activities in which engineers are currently engaged. Since a continuing liaison between the companies and faculty of the department is maintained, students receive assignments of progressive responsibility and sophistication that are usually more professionally rewarding than typical summer jobs.

The 6-A Internship Program is primarily designed to work in conjunction with the department’s five-year Master of Engineering degree program. Internship students may complete up to four assignments with their cooperating company—usually three summers and one regular term. While on internship assignment, students receive pay from the participating company as well as academic credit for their work.

In the year 2001 substantial changes were made to the 6-A Internship Program to maximize flexibility for 6-A students by allowing easy entrance and exit at any time. A new Fall 6-A recruitment has been added for seniors who wish to do an industry-based Master of Engineering thesis.

Undergraduate students may apply for admission to the 6-A Internship Program during the annual selection periods in the fall and spring terms. The department cannot guarantee the acceptance of a student into the program, since openings are limited. At the end of their junior year, most 6-A students can expect to gain admission to 6-PA, the Internship version of 6-P, the department’s five-year Master of Engineering degree program. 6-PA students do their MEng thesis at their participating company’s facilities. They can apply up to 48 units of work-assignment credit toward their MEng degree. Thus, completing the Master of Engineering program need not take longer under 6-PA than under the 6-P program.

6-A students who do not gain admission to 6-PA complete a minimum of two work assignments and receive the bachelor’s degree, normally at the end of four years. One of the work assignments may be used for the required Advanced Undergraduate Project, by including a written report and approval by a faculty member.

6-A students generally remain with the company with which they start the program. At the conclusion of the program, students are not obliged to accept employment with the company, nor is the company obliged to offer such employment.

Additional information about the 6-A Internship Program is available at the 6-A Office, Room 38-409E, MIT, 617-253-4644, and on the department website.

**DOCTORAL AND PREDOCTORAL PROGRAMS**

The programs of education offered by the Department of Electrical Engineering and Computer Science at the doctoral and predoctoral level have three aspects. First, a variety of classroom subjects in physics, mathematics, and fundamental fields of electrical engineering and
computer science is provided to permit students to develop strong scientific backgrounds. Second, more specialized classroom and laboratory subjects and a wide variety of colloquia and seminars introduce the student to the problems of current interest in many fields of research, and to the techniques that may be useful in attacking them. Third, each student conducts research under the direct supervision of a member of the faculty and reports the results in a thesis.

Three advanced degree programs are offered in addition to the Master of Engineering program described above. A well-prepared student with a bachelor’s degree in an appropriate field from some school other than MIT (or from another department at MIT) normally requires about one and one-half years to complete the formal studies and the required thesis research in the Master of Science degree program. (Students who have been undergraduates in Electrical Engineering and Computer Science at MIT and who seek opportunities for further study must complete the Master of Engineering rather than the Master of Science degree program.) With an additional year of study and research beyond the master’s level, a student in the doctoral or predoctoral program can complete the requirements for the degree of Electrical Engineer or Engineer in Computer Science. The doctoral program usually takes about four and one-half years beyond the master’s level, or five to six years beyond a bachelor’s degree.

There are no fixed programs of study for these doctoral and predoctoral degrees. Each student plans a program in consultation with a faculty advisor. As the program moves toward thesis research, it usually centers in one of a number of areas, each characterized by an active research program. Areas of specialization in the department that have active research programs and related graduate subjects include systems, communications, and control; computer science; artificial intelligence; electronics, computers, and systems; electromagnetics and dynamics; energy conversion devices and systems; materials and devices; VLSI system design and technology; communication and probabilistic systems; operations research; optics and quantum electronics; bioelectrical engineering; power engineering; and high-voltage engineering.

In addition to graduate subjects in electrical engineering and computer science, many students find it profitable to study subjects in other departments such as Biology, Economics, Linguistics and Philosophy, Management, Mathematics, Physics, and Brain and Cognitive Sciences.

The informal seminar is an important mechanism for bringing together members of the various research groups. About 16 seminars meet every week. In these, graduate students, faculty, and visitors report their research in an atmosphere of free discussion and criticism. These open seminars are excellent places to learn about the various research activities in the department.

Research activities in electrical engineering and computer science are carried on by students and faculty in laboratories of extraordinary range and strength, including the Laboratory for Information and Decision Systems, Research Laboratory of Electronics, Computer Science and Artificial Intelligence Laboratory, Center for Materials Science and Engineering, Laboratory for Electromagnetic and Electronic Systems, Laboratory for Energy and the Environment, Kavli Institute for Astrophysics and Space Research, Lincoln Laboratory, Media Laboratory, Francis Bitter Magnet Laboratory, Operations Research Center, Plasma Science and Fusion Center, and the Microsystems Technology Laboratories. Full descriptions of many of these laboratories, including a list of current projects, may be found in the section on Interdisciplinary Research and Study in Part 1.

Because the backgrounds of applicants to the department’s doctoral and predoctoral programs are extremely varied, both as to field (electrical engineering, computer science, physics, mathematics, biomedical engineering, etc.) and as to level (bachelor’s or master’s) of previous degree, no specific admissions requirements are listed. All applicants for any of these advanced programs will be evaluated in terms of their potential for successful completion of the department’s doctoral program. Superior achievement in relevant technical fields is considered particularly important.

Master of Science in Electrical Engineering and Computer Science

The general requirements for the degree of Master of Science are given in the section on Graduate Education in Part 1. The department requires that the 66-unit program consist of at least four H-level subjects which must include a minimum of 42 H-level units. In addition, a 24-unit thesis is required beyond the 66 units. Students working full-time for the Master of Science degree may take as many as four classroom subjects per term. The subjects are wholly elective and are not restricted to those given by the department. The program of study must be well balanced, emphasizing one or more of the theoretical or experimental aspects of electrical engineering or computer science.

Master of Science in Engineering and Management

The System Design and Management (SDM) program is a partnership among industry, government, and the university for educating technically grounded leaders of 21st-century enterprises. Jointly sponsored by the School of Engineering and the Sloan School of Management, it is MIT’s first degree program to be offered with a distance learning option in addition to a full-time in-residence option. For more information, see the program description in the Engineering Systems Division section in Part 2, or visit http://sdm.mit.edu/.

Electrical Engineer or Engineer in Computer Science

The general requirements for an engineer’s degree are given in the section on Graduate Education in Part 1. These degrees are open to those able students in the doctoral or predoctoral program who seek more extensive training and research experiences than are possible within the master’s program. Admission to the engineer’s program depends upon a superior academic record and outstanding progress on a thesis. The course of studies consists of at least 162 units, 90 of which must be graduate H-level, and the thesis requirements for a master’s degree.

Doctor of Philosophy or Doctor of Science

The general requirements for the degree of Doctor of Philosophy or Doctor of Science are given in the section on Graduate Education in Part 1. Doctoral candidates are expected to participate fully in the educational program of the department and to perform thesis work that is a significant contribution to knowledge. As preparation,
MIT students in the Master of Engineering in Electrical Engineering and Computer Science program will be expected to complete that program. Non-MIT students who have received a bachelor’s degree, but who have not completed a master’s degree program, will normally be expected to complete the requirements for the Master of Science degree described earlier, including a thesis. Students who have completed a master’s degree elsewhere without a significant research component will be required to register for and carry out a research accomplishment equivalent to a master’s thesis before being allowed to proceed in the doctoral program.

Details of how students in the department fulfill the General Institute Requirements for the doctoral program are spelled out in an internal memorandum. The department does not have a foreign language requirement, but does require an approved minor program.

Joint Program with the Woods Hole Oceanographic Institution/Course 6-W
The Joint Program with the Woods Hole Oceanographic Institution is intended for students whose primary career objective is oceanographic engineering. Students divide their academic and research efforts between the campuses of MIT and WHOI. The program is described in more detail at the end of Part 2.

Other Degree Programs

Computation for Design and Optimization
The Computation for Design and Optimization (CDO) master’s degree program is available to graduate students interested in the analysis and application of computational approaches to designing and operating engineered systems. The curriculum is designed with a common core that serves all engineering disciplines, and an elective component that focuses on particular applications. Current MIT graduate students can pursue a CDO master’s degree in conjunction with their departmental master’s or doctoral studies. For further information, see the program description in the Interdisciplinary Graduate Programs section in Part 2, or visit http://web.mit.edu/cdo-program/.

Leaders for Manufacturing Program
The Leaders for Manufacturing (LFM) program combines graduate education in engineering and management for those with two or more years of work experience who aspire to leadership positions in manufacturing or operations companies. This rigorous 24-month program combines subjects in technology and management. A required 6.5-month internship provides opportunity to complete a research project on site at one of LFM’s partner companies. The internship leads to a dual-degree thesis, culminating in two master’s degrees—an SM in management or an MBA, and an SM in engineering from the Department of Electrical Engineering and Computer Science. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description in the Engineering Systems Division section in Part 2, or visit http://lfm.mit.edu/.

Master of Science in Technology and Policy
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 TPP and either a specialization in technology or an applied social science such as political science or urban studies and planning. For additional information, see the program description in the Engineering Systems Division section in Part 2, or visit http://tppserver.mit.edu/.

Graduate students enrolled in the department may participate in the interdisciplinary centers described in Part 1, such as the Center for Biomedical Engineering and the Operations Research Center.

Fellowships and Research and Teaching Assistantships
Studies toward an advanced degree can be supported by personal funds, by an award such as the National Science Foundation Fellowship (which the student brings to MIT), by a fellowship or traineeship awarded by MIT, or by a graduate assistantship. Assistantships require participation in research or teaching in the department or in one of the associated laboratories. Assistants normally register for no more than two or three scheduled classroom or laboratory subjects, depending upon the conditions of their appointments, and may receive additional academic credit for their participation in the teaching or research program.

Inquiries
Additional information concerning graduate academic and research programs, admissions, financial aid, and assistantships may be obtained from the Electrical Engineering and Computer Science Graduate Office, Room 38-444, MIT, 617-253-4605, http://www-eecs.mit.edu/.

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The mission of the Engineering Systems Division (ESD) is to pursue the study of complex technological systems and products considered in their broader environmental, financial, legal, organizational, and political context. MIT established the division in 1999 with the charter to develop academic programs that educate future leaders in engineering systems; to serve as a model to broaden engineering education generally; and to expand the scope and practice of engineering.

The Engineering Systems Division collaborates with the engineering departments and with management and social science faculty in the other schools at MIT. It also actively develops innovative relationships with industry and government through collaborative global research projects and long-distance educational programs at remote sites.

Designing engineering systems is increasingly difficult as they increase in the size, scope, and complexity that result from globalization, new technological capabilities, rising consumer expectations, and increasing social requirements. Consequently, intelligent development of engineering systems calls for new frameworks of analysis and design that are different from those of the traditional paradigm of engineering science. The effective design of engineering systems requires a more integrative approach in which engineering systems professionals view the technological system as part of a larger whole. ESD is founded on the recognition that new approaches, frameworks, and theories must be developed to design these systems.

To achieve its objectives, the Engineering Systems Division focuses first on education and adding value for its associated educational programs: the Technology and Policy Program, the Master of Engineering in Logistics, the Leaders for Manufacturing Program, and the System Design and Management Program. The division also has developed new educational initiatives, such as the new doctoral program in engineering systems, building upon those programs to prepare students for the challenges and opportunities of the 21st century.

To support its educational programs, the Engineering Systems Division also initiates research focused on important national and international issues that have science and technology components. These build upon the existing research programs in the Center for Technology, Policy, and Industrial Development, and the Center for Transportation and Logistics.

ESD’s educational and research programs are deeply involved with industry, government, and engineering practice in general. Units within ESD have many formal ties to multiple enterprises as well as novel industry-academic relationships. Examples include: consortia formed around the International Motor Vehicle and the Lean Aerospace Programs in the Center for Technology, Policy, and Industrial Development; corporate and public affiliates programs of the Center for Transportation and Logistics, as well as its Integrated Supply Chain Management Program; and corporate partnerships of the Leaders for Manufacturing Program and the System Design and Management Program.

ESD provides the basis for a general education in the planning, design, and implementation of engineering systems and sponsors Master of Science and Master of Engineering degrees, as well as its interdisciplinary Doctor of Philosophy degree. The Master of Science programs are directed toward research and professional practice in specific areas: engineering systems; technology and policy; logistics; manufacturing; and system design and management. The doctoral program focuses on advanced research in engineering systems, integrating engineering and applied social sciences.

Application forms for all programs can be downloaded from http://web.mit.edu/admissions/graduate/. Applicants whose first language is not English must offer evidence of written and oral proficiency in English by taking the Test of English as a Foreign Language (TOEFL) and achieving a score equal to or higher than 257 for the computer-based test, 103 for the internet-based test, and 613 for the paper-based test. Registration forms for this test can be obtained by contacting toefl@ets.org. Information about the Graduate Record Examinations (GRE) and Graduate Management Admissions Test (GMAT) is available at gre-info@ets.org and gmat@ets.org. Applicants should refer to the details of each program concerning specific requirements for admission. Links to all of the programs can be found at http://esd.mit.edu/.

All programs except MLOG may offer student fellowships or graduate research or teaching assistantships. Information about these should be obtained directly from the individual programs.

Please refer also to the Academic Office of the Division (esgrad@mit.edu), and to the MIT Sloan School of Management for programs offering joint degrees.

MASTER’S PROGRAMS

Master of Science in Engineering Systems

The SM in Engineering Systems is an engineering degree available to students with an undergraduate degree in engineering or science. The degree validates a curriculum and a thesis focusing on the design and implementation of technological systems. The ESD SM can be a terminal degree that prepares for productive practice, or it can be obtained during the ESD PhD program. The ESD SM allows ESD faculty and students to work together on issues that are different from those covered by the other SM programs that are part of ESD. (These are the TPP, MLog, and SDM programs described in the subsequent sections.) It can also serve as the Engineering SM for students in the Leaders for Manufacturing Program described later.

Admission to the ESD SM is based upon academic performance in engineering or applied science, standardized test scores, demonstrable interest in engineering systems as a field of study, and letters of recommendation. Students wishing to apply for the ESD SM degree when they are already in an MIT graduate program should first discuss their interests with the ESD faculty and obtain the consent of an ESD faculty advisor in their field of interest to serve as advisor for their thesis. See the ESD admissions website for details: http://esd.mit.edu/esd_educational_programs/faqs_esd_sm_phd.html.

The ESD Education Committee makes admissions decisions once a year. Applications are due January 10. The ESD SM program begins in September. For additional information, please visit http://esd.mit.edu/esd_educational_programs/esd_sm.html first. To resolve subsequent issues, email the ESD Academic Office at esgrad@mit.edu or call 617-253-1182.

Master of Science in Technology and Policy

Students who want to pursue careers of leadership in the constructive development and use
of technology have not been accommodated by the traditional educational paths that train either technical or social science specialists. The Technology and Policy Program (TPP) focuses on the need for engineering leaders who are capable of dealing effectively with core technical issues in their full economic, political, and administrative contexts. TPP educates “leaders who are engineers and scientists,” persons who have strong technical foundations as well as the skills and ability to deal with important strategic issues concerning the intelligent and effective development of technology.

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. Many students combine TPP’s curriculum with complementary subjects to obtain dual degrees in TPP and either a specialized branch of engineering or an applied social science such as political science or urban studies and planning.

The 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. Because the overall objective is to prepare participants for effective professional practice, TPP stresses effective leadership and communication. It also encourages students to participate in TPP’s summer internship program, which places students in government and industry in the United States and around the world.

The TPP curriculum consists of three blocks of subjects and a research thesis. The first block is a required integrative subject in technology and policy and a set of program seminars focusing on leadership and presentation skills. The second block focuses on training in formal frameworks for policy development and consists of restricted electives in microeconomics, political economy, and legal processes. The third block comprises a minimum of three coherent electives that fulfill professional and research objectives.

Completion of the academic and research requirements of the TPP SM typically takes three or four terms.

The subjects required for the TPP degree include ESD.10 Introduction to Technology and Policy and the following subjects or their equivalents: 15.011 Economic Analysis for Business Decisions, ESD.103 Science, Technology, and Public Policy, and ESD.132 Law, Technology, and Public Policy. Students are strongly encouraged to take ESD.71 Engineering Systems Analysis for Design, particularly those considering doctoral studies in ESD.

The TPP curriculum normally begins in September. Applications are due by January 10.

All applicants should have a strong basis in engineering or science, and must take the GRE. Strong candidates for the program typically score in the top 10 percent of all three GRE areas: verbal, quantitative, and analytic writing. Applicants whose first language is not English must take the TOEFL exam and achieve a score equal or higher than 255 (610 for paper-based version). Participants in TPP should generally have two years of work experience and be able to demonstrate evidence of leadership and initiative in their professional or other activities.

Contact the TPP program office in Room E40-369, 617-253-7693, tpp@mit.edu, or visit http://tppserver.mit.edu/ for additional information.

Master of Engineering in Logistics

Initiated in the fall of 1998, the Master of Engineering in Logistics (MLOG) program is designed to supply the global logistics industry with a new type of supply chain professional, who is highly trained in both analytical problem solving and change management leadership. The one-of-a-kind professional degree program offered through ESD’s Center for Transportation & Logistics prepares graduates for logistics and supply chain management careers in manufacturing, distribution, retail, transportation, logistics, consulting, and software development organizations.

The MLOG degree is completed in nine months (September through May) on the MIT campus in Cambridge, MA. During that time, students take specialized classes taught by leading logistics and supply chain professionals in areas such as logistics systems, supply chain design, inventory planning, and transportation management. In addition, MLOG students are given the opportunity to work closely with corporate members of the Center for Transportation & Logistics on research projects and travel to our newest global logistics center in Spain—for a supply chain education that spans the globe.

The MLOG program requires 90 MIT credit units: eight required subjects and the completion of a thesis project. Students also take at least nine credit units of electives. Students who have already taken one of the required subjects at a graduate level elsewhere can petition to replace that subject with another elective.


The program is primarily for students with three to ten years of industry experience, but is open to anyone who can meet the entrance requirements. Applicants should have a background in college level calculus, economics, probability and statistics. All applicants for the MLOG degree must take the GRE General Test or GMAT. Applicants whose first language is not English must take the TOEFL exam and achieve a score equal to or higher than 255 (610 for paper-based exam).

The MLOG curriculum begins in September. There are two admission rounds. Round 1 deadline is January 12, 2007; Round 2 deadline is April 6, 2007. Applications should be sent to the MLOG Admissions Office.

For additional information, contact the MLOG Admissions Office, Room E40-367, 617-324-6564, mlog@mit.edu, or visit http://web.mit.edu/mlog/.

System Design and Management Program

MIT’s System Design and Management (SDM) Program, offered jointly by the School of Engineering and the MIT Sloan School of Management, is a master’s degree program for professional engineers who seek to build upon their technical backgrounds and advance to positions of leadership in their profession.

The SDM Program offers the degree of Master of Science in Engineering and Management. Students take subjects drawn from three areas: systems (systems engineering, architecture, and optimization), management, and a technical area of the student’s choosing.

SDM provides both on-campus instruction for full-time degree students and distance learn-
ing instruction for professional engineers who are continuing in their positions while enrolled in the program. The 13-month full-time program that begins in January requires 11 courses, 4 electives, and a thesis. The distance learning program requires 24 months to complete, with an initial January on campus followed by five semesters of distance education classes; students spend one semester in residence at MIT, and the total course requirements, including thesis, are the same as for the full-time, 13-month program.


All core and foundation subjects are taught on campus and via distance education. There are currently two track options for SDM students: Design and Product Development (PD). Elective selection is determined by the track chosen. Students take one engineering and one management elective, and either two design or product development electives, depending on the track (Design or PD) chosen.

The ideal applicant for the SDM program will have a master’s degree in engineering or the equivalent and three or more years as a professional engineer, including experience as a team leader. Students with a bachelor’s degree and five years of professional experience, including leadership experience, are encouraged to apply.

The SDM Program begins in January. Potential student fellow may apply via the web at http://sdm.mit.edu/apply.html. For additional information contact the SDM Program Office in Room E40-315, 617-253-1055, sdm@mit.edu, or visit http://sdm.mit.edu/.

Leaders for Manufacturing
The Leaders for Manufacturing (LFM) Program is an educational and research partnership between global operations companies and MIT’s Schools of Engineering and Management. Its objective is to discover, codify, teach, and otherwise disseminate guiding principles for world-class manufacturing.

The Leaders for Manufacturing Program leads to two MIT master’s degrees, an SM from ESD or a participating engineering department and an MBA or SM from the Sloan School of Management. In addition to ESD, seven engineering master’s programs participate in LFM: Aeronautics and Astronautics, Biological Engineering, Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, and Mechanical Engineering.

The 24-month, dual-degree LFM Program integrates engineering and management disciplines and emphasizes teamwork, management of change processes, and learning by doing. The rigorous curriculum is developed and taught by faculty from both schools. It includes a six-and-one-half-month internship for on-site research. The coursework and research culminate in a single thesis.


To complete the requirements for the LFM program, students also take engineering subjects in product development as well as additional electives in management and their engineering concentration.

The LFM academic program begins in June. Students are generally required to have at least two years of full-time work experience. Applications are due in December and can be made either through a participating engineering department or through the Sloan School of Management. All applicants must take either the GRE, if applying through any program in the School of Engineering, or the GMAT, if applying through the Sloan School of Management.

For additional information, visit the LFM website at http://lfm.mit.edu/, contact the LFM program office at lfm@mit.edu or 617-253-1055, or see any of the participating engineering departments and the Sloan School of Management.

DOCTORAL PROGRAMS
Engineering Systems
The doctoral program in Engineering Systems enables students to develop technical expertise and apply new research methodologies to address problems in the development and implementation of engineering and technological systems. The ESD PhD requires engineers and other technical specialists to conduct original scholarship on complex technical systems, in order to advance theory, policy, or practice.

The ESD PhD builds focused depth of understanding and breadth of knowledge in the areas of systems theory, systems policy, and systems evaluation (see http://esd.mit.edu/esd_educational_programs/doctoral.html). A doctoral seminar is required for all candidates. Beyond the basics, each doctoral student takes a sequence of in-depth additional subjects in a major that covers technical systems or methods and a minor in an engineering discipline or other appropriate area of expertise such as policy or management.

It should be noted that the concept of systems has a long history and is used in many ways. While the focus on engineering systems narrows the domain of study to complex, technical systems, the full range of theory and principles developed around various concepts of systems may be relevant to a student doing doctoral research in ESD.

For example, the domain that includes systems policy reflects the view that engineering systems is inherently an applied, interdisciplinary field of study. As such, advanced doctoral research and subsequent career success in engineering systems requires at least one additional area of applied expertise. In general, the specification of an area of applied expertise also involves the identification of specific engineering systems that are of particular interest.
The ESD PhD program provides a platform for a range of research interests. Faculty and students can construct specialty foci beyond the ESD core and the minimum requirements to demonstrate technical expertise. These can and have included the environment, manufacturing, policy, information, system architecture, etc. The student and the doctoral committee collaboratively define the details. As indicated in the next section, the ESD PhD program has a special track in Technology, Management, and Policy.

Students can enter the ESD PhD in many ways. They can do so either without previous graduate education, or from time spent in a master’s program at MIT or other institutions. Either way, the nominal time to the ESD PhD is five years, including a master’s degree such as the SM. In any case, students are expected to complete an SM or equivalent thesis or paper sometime before their graduation.

Admission to the ESD PhD program is based upon outstanding academic performance in engineering or applied science, standardized test scores, demonstrable interest in engineering systems as a field of study, and letters of recommendation. Students wishing to apply to the ESD PhD program when they are already at MIT should first discuss their interests with ESD faculty members in their field of interest and obtain their support. See the ESD admissions website for details at http://esd.mit.edu/esd_educational_programs/admissions.html.

The ESD Education Committee makes admissions decisions once a year. Applications are due January 10. The ESD PhD program begins in September. For additional information, please visit the website at http://esd.mit.edu/degree_programs/ first, and see the Frequently Asked Questions about Admissions at http://esd.mit.edu/esd_educational_programs/faqs_sm_phd.html. To resolve subsequent issues, email the ESD Academic Office at esdgrad@mit.edu or call 617-253-1182.

Technology, Management, and Policy

The doctoral track in Technology, Management, and Policy (TMP) is a specialty within the ESD PhD program. It promotes a strong, in-depth integration of technology and applied social science, with a particular emphasis on policy. Each student’s program focuses simultaneously on a technology discipline and an applied social science such as economics, management, or political science. This doctoral track focuses on original, generalized research on technological systems, with an emphasis on the societal implications of the system. TMP graduates hold positions on the faculties of major universities in the United States and worldwide. The doctoral track in Technology, Management, and Policy promotes a strong, in-depth integration of technology and applied social science, with a particular emphasis on policy. This doctoral track focuses on original, generalized research on technological systems, with an emphasis on the societal implications of the system. TMP graduates hold positions on the faculties of major universities in the United States and worldwide.

RESEARCH CENTERS

Center for Engineering Systems Fundamentals

ESD’s center for Engineering Systems Fundamentals (CESF) was founded in September 2005 to conduct research on the fundamentals and cross-cutting issues in engineering systems. CESF is engaged in several areas, among them developing seminars and other mechanisms to discuss engineering systems fundamentals; collaborating with faculty to bring in resources for CESF and shape its relationships with ESD’s other research centers, the Center for Technology, Policy, and Industrial Development and the Center for Transportation and Logistics; and sponsoring an engineering systems book series and a biannual international symposium on engineering systems fundamentals. CESF seeks to establish cross-cutting research projects on problems of national significance that require integration of the methods of engineering, management, and the social sciences. Through the interdisciplinary framing, formation, and solution of sociotechnical systems problems, this process should lead to the creation of engineering systems fundamentals.

Center for Technology, Policy, and Industrial Development

MIT’s Center for Technology, Policy, and Industrial Development (CTPID) is an interdisciplinary research and educational center addressing global technology and policy issues through sustained partnerships with industry, government, and academia. These partnerships are aimed at supporting global economic growth and advancing policies that preserve the environment and benefit society at large.

Center programs include the Communications Futures Program, Ford-MIT Alliance, IMVP, Lean Aerospace Initiative, Labor Aerospace Research Agenda, Lean Sustainment Initiative, Information Quality Program (MIT IQ), Materials Systems Laboratory, and the Technology and Law Program.

For further information on CTPID and its programs, see Part 1, Interdisciplinary Research and Study.

Center for Transportation & Logistics

For more than 30 years, the MIT Center for Transportation & Logistics (CTL) has been a world leader in supply chain management and transportation education and research. CTL is part of the Engineering Systems Division in the School of Engineering, and engages in three principal activities: research, outreach, and education.

Research

The center’s world-renowned research programs directly involve over 75 faculty and research staff from a wide range of academic disciplines, as well as researchers in various affiliate organizations around the world. CTL has three main research programs: Supply Chain Management, Transportation, and the MIT AgeLab.

Supply Chain Management

In the field of supply chain management, CTL has made major knowledge contributions and helped numerous companies gain competitive advantage from its cutting-edge research. Research projects include:

- **Supply Chain 2020:** A multiyear project to analyze the factors that are critical to the success of future supply chains.
- **Supply Chain Response to Disruption:** A study of the resilience of supply chains when subject to major disruptions such as natural disasters and terror attacks.
- **Demand Management:** A project investigating advanced strategies, processes, methods, and technologies for integrating demand and supply management in both planning and real time.
- **Innovations in Transportation Procurement:** Studying new methods for procuring transportation services such as combinatorial auctions.
- **Outsourcing & Postponement:** Delaying the final configuration of a product can cut inventory costs and improve customer service. CTL
is studying the supply chain strategy and the implications for employment patterns in manufacturing.

Transportation

CTL research spans every aspect of transportation, including all its modes. Research projects include:

- MIT/Transit Professional Development Program: A collaborative undertaking of applied research involving individual partnerships between MIT and major transit agencies engaged in large infrastructure projects.
- MIT Program in Intelligent Transportation Systems: Focusing on applications of modern information technologies to transportation systems, the project looks at congestion, environmental factors, and flow efficiency.
- National Center of Excellence for Aviation Operations Research: Formed by the Federal Aviation Administration in 1996 to support collaborative research in aviation operations, the center comprises a consortium of universities with 20 public and private sector organizations.

The AgeLab

The MIT AgeLab is an innovative lab that conducts research to improve quality of life for older adults and those who care for them. It creates new ideas and translates technology into practical solutions that improve people’s functioning throughout the life span. The AgeLab works with business, academic, and government leaders to influence public policy on issues surrounding aging, including transportation, health, housing, and investments.

Outreach

The gateway to the center’s research is CTL’s Corporate Outreach Program. Through this multifaceted program, industry and CTL collaborate to turn innovative research into market-winning commercial applications. CTL currently has more than 35 corporate partners worldwide.

Education

In education, MIT is consistently ranked first among business programs in logistics and supply chain management. CTL graduate degrees and executive-level programs are unsurpassed for quality and market relevance. CTL’s Master of Engineering in Logistics (MLOG) program attracts business professionals from across the globe to participate in its intensive logistics and supply chain management program. In just nine months, MLOG students hone their supply chain expertise through challenging coursework, extensive industry interaction, and cutting-edge research. There is also a PhD program in Logistics and Supply Chain Management, which is administered by the Engineering Systems Division.

In partnership with the Zaragoza Logistcs Center (ZLC), a research institute associated with the University of Zaragoza, in Spain, CTL has established the MIT-Zaragoza International Logistics Program. An innovative feature is that the ZLC is constructing its building in the middle of PLAZA, one of the largest logistics parks in the world. ZLC offers master’s, doctoral, and executive education programs, taught in both English and Spanish. The international master’s program (ZLOG) is modeled on MIT’s Master of Engineering in Logistics (MLOG) program. ZLOG and MLOG students study together on both campuses during January, and ZLC doctoral students also have the opportunity to study at MIT. ZLC graduates receive degrees from the University of Zaragoza and certificates from the MIT-Zaragoza International Logistics Program.

Through CTL, MIT is the lead university in Federal Region I of the University Transportation Centers program administrated by the US Department of Transportation. Through this program, full and partial fellowships are awarded to graduate students in transportation. Also, research and teaching assistantships are available through this program. Undergraduates also may participate in sponsored research through the Undergraduate Research Opportunities Program.

Students interested in studying supply chain management and logistics, or in learning more about the center and its programs, should write to Chris Caplice, Center for Transportation and Logistics, MIT, 77 Massachusetts Ave, Room E40-365, Cambridge MA 02139-4307, caplice@mit.edu, or visit http://web.mit.edu/ctl/.

Students interested in the Master of Science in Transportation program administrated through the Department of Civil and Environmental Engineering should contact Nigel Wilson, MIT, 77 Massachusetts Ave., Room 1-238, Cambridge, MA 02139-4307, nhmw@mit.edu. Several departments offer both master’s and doctoral degrees that allow a focus on transportation, including Aeronautics and Astronautics, Civil and Environmental Engineering, the Engineering Systems Division, and Urban Studies and Planning.

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Materials science and engineering is a field broadly based in chemistry, physics, and the engineering sciences. The field is concerned with the design, manufacture, and use of all classes of materials (including metals, ceramics, semiconductors, polymers, and biomaterials), and with the environmental, health, economic, and manufacturing issues relating to materials. Materials science and engineering is a field critical to future economic and environmental well-being.

Materials science emphasizes the study of the structure of materials and of processing—structure-property relations in materials. It is the physics and chemistry of real materials. Almost all the properties of importance to an engineer are structure-sensitive—that is, they can be modified in significant ways by changing the chemical composition, the arrangement of the modified in significant ways by changing the crystals or other macroscopic units of a solid. To understand how the useful properties of a material can be modified, it is necessary to understand the relationships between structure and properties and how the structure can be changed and controlled by the various chemical, thermal, mechanical, or other treatments to which a material is subjected during manufacture and in use. The fundamental understanding of materials developed through materials science has replaced empiricism as the basis for discovery of new materials. Whole classes of new materials such as semiconductors, superconductors, and some high-temperature alloys have their roots in modern materials science.

All recent achievements in materials have depended as much on advances in materials engineering as they have on materials science. When developing processes for preparation and production of materials, and when designing materials for specific applications, the materials engineer must have a grasp of the modern engineering sciences, including heat and mass transfer and chemical kinetics. He or she must also have a proper concern for economic, social, and environmental factors. Materials processing is a major part of materials engineering. Improved performance of materials depends directly on advances in processing. There are also many examples of challenging engineering problems in reducing the cost and improving the productivity of industrial processing of materials. The department has strong academic and research activities in all aspects of the processing of materials.

The links between materials engineering and materials science are very strong, and the two activities are interwoven in the department. There are some subjects that all students of materials should know: thermodynamics, kinetics, and certain aspects of solid mechanics, physics, and chemistry. Core subjects in these areas are provided at the undergraduate and graduate levels. In addition, subjects covering a wide variety of topics, from solid-state physics to the analysis of materials systems, are offered. By selecting appropriate subjects, the student can follow many different paths through the science and engineering of materials, with emphasis on engineering, science, or a mixture of the two.

Materials science and materials engineering disciplines seek to identify and understand the principles and phenomena that are basic to all materials. Many large industries today manufacture products containing a great variety of different materials, and their materials engineers must acquire a working understanding of the basic behavior of all of them. However, there are also many large industries in which a single class of material (e.g., steel, polymers, glasses) is manufactured and processed, and their materials experts must have a knowledge of various aspects of the science and engineering of one class of material. Thus, lecture and lab subjects are provided in the department that enable a student to specialize in the science and engineering of ceramics, electronic materials, metals, polymers, or biomaterials.

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 challenging opportunities in a wide variety of important positions in operations, development, and research in the fast-growing electronics industry, in aerospace, in consumer industries, in biomaterials and medical industries, and in the basic materials preparation and producing industries.

Archaeology and Archaeological Science
The principles of materials science and materials engineering have particular relevance to the study of archaeological materials. Laboratory investigation of ancient and pre-industrial artifacts of metal, ceramic, stone, cloth and other materials enables archaeologists to reconstruct the materials technologies behind the design and production of objects in prehistory. The Center for Archaeological Materials is developing what might be called the materials science of material culture, exploring the relations between ancient people and their material world.

Archaeology is the systematic study of humanity in the past, concerned with reconstructing the environments in which people lived and the ecological systems in which they functioned. Encompassing the study of ancient technologies and other human activities, as well as peoples’ social organization, religious beliefs, and every aspect of human culture, archaeology covers all of human history, from the time of the earliest human beings up to the present.

Because archaeology is so broad in scope and the data on which it relies derive primarily from field survey and excavations, a range of disciplines provides its foundation. Geology, anthropology, materials science, art history, and biology are among these fundamental fields. Archaeological science represents an approach to archaeology that utilizes modern science and engineering principles and methods to tackle pressing archaeological issues—for example, reconstructing time, place, and human ecologies of the past, or determining the materials technologies that transform natural materials into cultural objects.

MIT’s archaeology education programs reflect particular strength in archaeological science research. The Bachelor of Science in Archaeology and Materials as recommended by the Department of Materials Science and Engineering derives from the 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 university departments of anthropology, archaeology, and engineering.
UNDERGRADUATE STUDY

The Department of Materials Science and Engineering offers three 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 Accreditation Board for Engineering and Technology (ABET); Course 3-A, leading to the Bachelor of Science without specification, provides greater flexibility to the student in designing his or her professional program, and is often taken by pre-med, pre-law, or pre-MBA students; and Course 3-C provides a Bachelor of Science in Archaeology and Materials. The department 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 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 later with some loss of scheduling flexibility.

The first four 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 a 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 an internship report based on a laboratory group project. Undergraduate students also have access to extensive facilities for research in materials as part of 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.

The department has modern undergraduate materials teaching laboratories containing a wide variety of materials processing and characterization equipment. A new undergraduate laboratory opened in 2003, including facilities for biomaterials research, chemical synthesis, and physical and electronic properties measurement. Other departmental facilities include preparation and characterization of refractory and electrical ceramics and glasses, metallic and nonmetallic crystals, and polymers. Equipment is available for the study of heat and mass flow and for thermodynamic and kinetic investigations at high temperatures. Deformation, solidification, joining, and thin film deposition may be carried out. Materials may be characterized by optical and electron microscopy techniques, diffraction, and spectroscopy, and there is equipment for a variety of electrical, optical, magnetic, and mechanical property measurements.

Students may substitute industrial internship reports (12 units of 3.930/3.931 Industrial Practice) for the senior thesis (3.014). Students should 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 a student with industrial experience concurrently with academic work through cooperative work assignments matched to the student’s capabilities. Together with a company representative, a faculty advisor is assigned to each student to assist as cosupervisor during his or her work assignments. Care is taken to ensure a more challenging and rewarding experience than is typical of most summer jobs. Students earn a salary during their work periods and also receive academic credit. Growth in job responsibility is expected as the student progresses.

Students who wish to go on to graduate school under the auspices of the Engineering Internship Program have the opportunity to earn an SM degree. At the end of the senior year, such students complete two terms of industrial practice and a minimum of one term of on-campus study, during which time they may complete the subject requirements of the SM degree and an SM thesis. Students exercising this option must follow the normal procedures for application to the graduate school.

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 conventional Course 3 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. 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 program.

The curriculum requirements for Course 3-A are similar to, but more flexible than, those for Course 3. Five subjects chosen from the core (3.012; 3.016, 18.03, or 18.034; 3.021, 3.016, 1.00, or 6.001; 3.022, 3.024, 3.032, 3.034, 3.042, and 3.044) and one laboratory subject (3.014) are required, along with any three additional subjects (36 units) selected from the list of Restricted Electives shown under Course 3. In addition to these nine subjects, the student should develop a program of six planned elective subjects appropriate to the student’s stated goals. CI-M designated subjects for Course 3-A include 3.014, 2.009, 2.671, 3.042, 3.155J, 5.32, 5.33, 6.021/2.791/20.370J, or 7.02.
Bachelor of Science in Materials Science and Engineering/Course 3

General Institute Requirements (GIRs)          Subjects          Units
Science Requirement                                      6
Humanities, Arts, and Social Sciences Requirement             8
Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 3.012 and 3.021] in the Departmental Program] 2
Laboratory Requirement [can be satisfied by 3.014 in the Departmental Program] 1
Total GIR Subjects Required for SB Degree                      17

Communication Requirement
The program includes a Communication Requirement of 4 subjects:
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics).

Required Subjects
3.022 Fundamentals of Materials Science and Engineering, 15; REST          128–138
3.044 Materials Laboratory, 12; LAB, CI-M

One of:
3.016 Mathematical Methods for Materials Scientists and Engineers, 12; 18.02
18.03 Differential Equations, 12; REST; 18.02 or 18.014
18.034 Differential Equations, 12; REST; 18.02 or 18.014

One of:
3.021 Introduction to Modeling and Simulation, 12; REST; 18.03*
1.00 Introduction to Computers and Engineering Problem Solving, 12; REST; 18.01
6.006 Structure and Interpretation of Computer Programs 15; REST
3.016 Mathematical Methods for Materials Scientists and Engineers, 12; 18.02*

Restricted Electives\(1\)
3.016 Mathematical Methods for Materials Scientists and Engineers, 12; 18.02*
3.021 Introduction to Modeling and Simulation, 12; 18.03*
3.044 Materials Laboratory, 12; 3.012, 3.014, 3.022, 3.024, or permission of instructor
3.046 Thermodynamics of Materials, 12; REST; 18.03*
3.048 Advanced Materials Processing, 12; 3.022, 3.024
3.051J Materials for Biomedical Applications, 12;
3.091T, 7.012*, 3.012*
3.052 Nanomechanics of Materials and Biomaterials, 12; 3.032*
3.053J Molecular, Cellular, and Tissue Biomechanics, 12;
18.02T, 7.102*
3.065 Polymer Physics, 12; 3.012*
3.064 Polymer Engineering, 12; 3.032*, 3.044

3.069 Ceramics Processing, 12; 3.044*
3.07 Introduction to Ceramics, 12; 3.012*
3.071 Diffraction and Structure, 12; 3.024
3.072 Symmetry, Structure and Tensor Properties of Materials, 12; 3.07
3.080 Economic and Environmental Issues in Materials Selection, 12; 3.012, 3.014, 3.022, 3.024, or permission of instructor
3.14 Physical Metallurgy, 12; 3.012, 3.022, 3.032*
3.15 Electrical, Optical, and Magnetic Materials and Devices, 12; 3.044*
3.153J Nanoscale Materials, 12; 3.044*
3.155J Micro/Nano Processing Technology, 12; CI-M

Departmental Program Units That also Satisfy the GIRs (39)
Unrestricted Electives                                     48

Total Units Beyond the GIRs Required for SB Degree        185–195

No subject can be counted both as part of the 17-subject GIRs and as part of the 185–188 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

Notes
\(1\) Alternate prerequisites are listed in the subject description.
\(2\) Students may elect 9–12 units.
\(3\) Substitution of similar subjects may be permitted by petition.
\(4\) These subjects can count as part of the core or as restricted electives, but not both.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

As an example of a 3-A program, a student planning a career in medicine might select the following subjects in addition to the above requirements in order to satisfy the premedical requirements recommended by the MIT Careers Office: 7.02, 5.12, 5.13, 5.310, 7.05.

Students considering the 3-A program should contact the departmental advisor (currently Professor David Roylance), who will counsel the student more fully on the academic considerations involved. Under his guidance, 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. Students are 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 formal 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 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 non-industrial 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: 3.986; 3.985J; two other HASS electives, from among those currently offered in this subject area: 3.094, 3.982, 3.983, 3.987, 3.988, 3.993. The department does not seek formal ABET accreditation for the 3-C program. Students may contact Professor Heather N. Lechtman for more information.

### Minor Program

The Minor in Materials Science and Engineering consists of six undergraduate subjects totalling at least 72 units from the list of Required Subjects and Restricted Electives in the departmental program, with at least one of these taken from the list of Restricted Electives. With the approval of the minor advisor, it may be possible to substitute one subject taken outside the department for one of the Course 3 subjects in the minor program, provided that the coverage of the substituted subject is similar to one of those in the departmental program.

The department’s minor advisor, currently Professor David Roylance, will ensure that individual minor programs form a coherent group of subjects. Because of the breadth of the undergraduate program in the department, and the variety of possibilities for specialization, the minor program is flexible in its composition. Examples of minor programs in Materials Science and Engineering, with specializations in the areas of biomaterials, ceramics, electronic materials, metallurgy, and polymers, can be

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

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Requirement</td>
<td>[3.014 or 12.119 in the Departmental Program]</td>
<td>1</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>[can be satisfied by 3.012, 3.021 or 12.001 in the Departmental Program]</td>
<td>2</td>
</tr>
<tr>
<td>Science Requirement</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>[can be satisfied by 3.986, 3.987, 3.985J, and 21A.100; and 3.982, 3.983, or 3.988 in the Departmental Program]</td>
<td>8</td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

### Communication Requirement

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

### PLUS Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics).

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.012 Fundamentals of Materials Science, 15, REST</td>
<td>152–162</td>
</tr>
<tr>
<td>3.014 Materials Laboratory, 12, LAB, CI-M</td>
<td>3.016 Mechanical Properties of Materials, 12; 3.016* or 3.044 Materials Processing, 12; 3.022, 3.016*</td>
</tr>
<tr>
<td>One of: 3.016 Mathematical Methods for Materials Scientists and Engineers, 8; 18.02</td>
<td>3.012 Thesis, 9(1)</td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; 18.02 or 18.014</td>
<td>3.985J Archaeological Science, 9, HASS; 3.091*</td>
</tr>
<tr>
<td>18.034 Differential Equations, 12, REST; 18.02 or 18.014</td>
<td>3.986 The Human Past: Introduction to Archaeology, 12; HASS-D</td>
</tr>
<tr>
<td>One of: 3.021 Introduction to Modeling and Simulation, 12, REST; 3.016 or 3.091*</td>
<td>3.987 Human Origins and Evolution, 9, HASS</td>
</tr>
<tr>
<td>1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; 18.01</td>
<td>3.990 Seminar in Archaeological Method and Theory, 6; 3.986, 3.985J, 21A.100</td>
</tr>
<tr>
<td>6.001 Structure and Interpretation of Computer Programs 15, REST</td>
<td>12.001 Introduction to Geology, 12, REST</td>
</tr>
<tr>
<td>3.022 Microstructural Evolution in Materials, 12; 3.012</td>
<td>12.110 Sedimentary Geology, 12; 12.001</td>
</tr>
<tr>
<td></td>
<td>or 12.119 Analytical Techniques for Studying Environmental and Geologic Samples, 12, LAB</td>
</tr>
<tr>
<td></td>
<td>21A.100 Introduction to Anthropology, 12, HASS-D</td>
</tr>
</tbody>
</table>

### Restricted Electives(1)

One subject from the following list:

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.069 Ceramics Processing, 12; 3.044*</td>
</tr>
<tr>
<td>3.077 Introduction to Ceramics, 12; 3.012*</td>
</tr>
<tr>
<td>3.14 Physical Metallurgy, 12; 3.015, 3.022, 3.012*</td>
</tr>
<tr>
<td>3.051 Materials for Biomedical Applications, 12; 3.091*, 3.012*</td>
</tr>
<tr>
<td>3.052 Nanomechanics of Materials and Biomaterials, 12; 3.032</td>
</tr>
</tbody>
</table>

### Departmental Program Units That also Satisfy the GIRs (90)

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>97</td>
</tr>
</tbody>
</table>

### Total Units Beyond the GIRs Required for SB Degree

180–193

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

### Notes

* Alternate prerequisites are listed in the subject description.

(1) Students may elect up to 9–12 units.

(2) Substitution of similar subjects may be permitted by petition.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
obtained from the department. Other suitable programs may be composed through consultation between students, the minor advisor, and the Undergraduate Committee.

The Minor in Archaeology and Materials (3-C) consists of six undergraduate subjects totaling 72 units. The five required subjects are 3.012 Fundamentals of Materials Science and Engineering, 3.014 Materials Laboratory, 3.022 Microstructural Evolution in Materials, 3.986 The Human Past: Introduction to Archaeology (HASS-D), and 3.984 Archaeological Science (HASS). The sixth subject is an elective from the Archaeology and Archaeological Science subject listings. With the approval of the minor advisor, it may be possible to substitute one subject taken outside the Course 3 program provided the coverage is equivalent. The department’s 3-C minor advisor, currently Professor Heather Lechtman, will ensure that the minor program forms a coherent group of subjects.

For a general description of the minor program, refer to the section on Undergraduate Education in Part 1.

Inquiries
Additional information regarding undergraduate programs may be obtained from Professor Caroline Ross, Room 13-4005, MIT, 617-258-0223, carross@mit.edu, or the Student Services Office, Room 35-413, 617-258-5816.

GRADUATE STUDY
Departmental Degrees and Fields
The Department of Materials Science and Engineering offers the degrees of Doctor of Philosophy and Doctor of Science in Materials Science and Engineering. It offers the degrees of Master of Science in Materials Science and Engineering, and Master of Engineering.

The department’s Master of Engineering (MEng)—an engineering project–based, rather than a research-based, degree program—is designed for completion in 12 months. Course work and projects begin in the fall and continue through the academic year and into the following summer. This program includes options for either industry-based or campus-based projects.

The doctoral degree fields are described briefly below. Subject descriptions appropriate to the degree requirements in each of these fields are provided in Part 3. The subjects 3.20 Materials at Equilibrium, 3.21 Kinetic Processes in Materials, 3.22 Mechanical Properties of Materials, and 3.23 Electrical, Optical, and Magnetic Properties of Materials are basic to all doctoral degree programs and constitute a required core for all graduate students enrolled in doctoral programs in the department. This requirement may be partially waived upon petition to the Departmental Committee on Graduate Students if it can be demonstrated that equivalent coverage of this material has been secured in previous study.

The various graduate fields are not rigidly defined. Each member of the departmental faculty works in at least two of these fields and a number of subjects appear in common on the lists of elective subjects in each academic program; there is a great deal of interaction between the fields. The graduate fields are also coupled with other activities on materials within the Institute. Faculty from other departments participate in the departmental teaching and research in these fields. Subjects offered by other departments are, wherever appropriate, included in the recommended electives, and many departmental students participate in multidisciplinary research projects with students and faculty from various parts of the Institute.

Students are expected to learn the fundamentals of their chosen field and to develop a deep understanding of one or more significant aspects of it. The general examinations for the doctoral degree are designed accordingly. A full range of advanced-level subjects is offered in each graduate field, and arrangements can be made for individually planned study of any topic. In addition to 3.20 through 3.23, students are required to take further subjects designated by their academic program and a two- or three-subject minor program. Two additional subjects are required, as recommended by a student's thesis committee.

A large and active research program on the structure and properties, preparation, and processing of materials, with emphasis on ceramics, electronic materials, metals, polymers, and biomaterials, is conducted in the department. Graduate research is an important part of the educational process, and emphasis is placed on the research thesis. Students choose research projects from many alternative opportunities that exist within the department, and work closely with an individual faculty member. 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 are also members of the Center for Materials Science and Engineering, which provides and maintains excellent central facilities, or the Materials Processing Center. Both centers provide interdisciplinary research opportunities as described in Interdisciplinary Research and Study in Part 1.

Electronic, Photonic, and Magnetic Materials
This program includes the science and technology of materials for electrical, magnetic, and optical device applications. It is concerned with the design and fabrication of useful materials and devices through understanding and control of the interplay between electronic, magnetic and optical properties, the micro- and nanostructure of materials (atomic arrangements, defects, interfaces, phase constitution, and morphology), and processing methods. Research within this field includes materials processing in bulk and thin-film form; device fabrication; characterization of the semiconducting, dielectric, optical, and magnetic properties of materials and devices; and theoretical study of the characteristics of bulk materials, thin-film materials and interfaces and their implications for devices.

Bio- and Polymeric Materials
This program concentrates on the science and technology of synthetic and natural materials characterized by carbon-bonded, long chain molecules of seemingly limitless architectural diversity, and their composites with inorganic materials. Polymer and nanocomposite processing by molecular-level assembly, self-assembly, and field-directed approaches are employed to create new materials displaying a wide range of structure and properties. Materials science and engineering principles are applied to the development of new products and therapies including photonic devices, battery electrolytes, organic
Part 1: Master of Science in Materials Science and Engineering

This program encompasses the study of the fundamental principles that underlie the structure and properties of materials. These subjects offer adequate preparation for most of the department's advanced graduate subjects.

LEDs, filtration membranes, highly recyclable plastics, resorbable implants, biosensors, and drug delivery devices.

**Structural and Environmental Materials**

The program on structural and environmental materials encompasses the study of the mechanical response of materials to internal and external stimuli, as well as the design and use of materials to minimize environmental impact. Research topics in the area of structural materials include microelectromechanical systems (MEMS), nanomechanics, functionally graded materials, superalloys, ceramic turbine blades, polymers, biomimicking of natural structural materials, and mechanics of cellular materials. Topics in environmental materials include materials processing to minimize environmental impact, recycling of materials, materials for energy conversion and storage (e.g., advanced battery systems, fuel cells, solar photovoltaics, smart windows, hydrides), and sensors and actuators for environmental monitoring and control.

**Emerging, Fundamental, and Computational Studies in Materials Science**

This program encompasses the study of fundamental and emerging concepts and technologies in materials science and engineering. The common principles that underlie the structure and properties of materials are those associated with electronic structure and bonding, atomic arrangement, phase stability, and the role of imperfections and microstructure. Fundamental phenomena considered include structural and phase transformations, reactivity, mass and charge transport, and the optical, electronic, and mechanical response to internal and external stimuli. Tools of study include theory, computer modeling, and experimental characterization methods such as TEM and diffraction. This program also stimulates the integration of important developments from other fields such as mathematics, biology, physics, and economics into materials science and engineering, and allows students to propose relevant interdisciplinary course programs that may lead to emerging disciplines in materials science and engineering.

**Interdisciplinary Doctoral 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 additionally 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.

**HST Doctoral Program in Medical Engineering/Medical Physics**

A joint PhD program in medical materials science and engineering is offered in conjunction with the Harvard-MIT Division of Health Sciences and Technology (HST). Candidates complete coursework in one of the four graduate degree program disciplines in the Department of Materials Science and Engineering before continuing with medical science coursework and clinical training in the HST curriculum. The doctoral thesis research concerns a fundamental and clinically important problem involving medical applications of materials science and engineering. Research can be carried out within the department or at one of the area hospitals affiliated with HST. For information on application procedures and other requirements, see the program description under the Harvard-MIT Division of Health Sciences and Technology in Part 2.

**Master of Science in Materials Science and Engineering**

The department offers a Master of Science degree in materials science and engineering, which may be taken simultaneously with other departmental or interdepartmental offerings, such as the Leaders for Manufacturing program. The general requirements for the master's degree are given in the section on Graduate Education in Part 1.

The coherent program of subjects (32 units, though not necessarily all Course 3 subjects) must be approved by one of the Master’s Degree Registration Officers in Course 3. Of the 66 total units required for the master's degree, 42 graduate degree credits are required to be in Course 3 subjects at graduate H-level. The thesis must have significant materials research content and an internal departmental thesis reader is required if the student’s advisor is outside Course 3. Subjects 3.577, 3.80j, 3.81j, and 3.83j may not be used to satisfy the departmental requirement that students earn 42 graduate H-level credits in Course 3 subjects.

The department may also recommend awarding a master's degree without departmental specification; the general requirements are given in the section on Graduate Education in Part 1. The thesis must be materials-related, and an internal departmental thesis reader is required if the advisor is outside Course 3.

**Master of Engineering Program**

The department’s Master of Engineering (MEng) program covers the fundamentals of the engineering discipline and provides exposure to the tools and experience of engineering practice. This program differs significantly from the research-based SM and PhD degrees.

The MEng program targets three categories of students: those continuing with graduate school immediately following their undergraduate experience, experienced professionals who are returning for “retooling” for a new career or job, and experienced professionals who are sent at company expense to prepare for new or increased job responsibilities. Students are not required to have an undergraduate degree in materials science and engineering, but a strong engineering background is expected.

The program begins in the fall and has a fixed length of 12 months. In the fall, students take two overview subjects specifically designed for the MEng program. These subjects are designed to distill to 24 units the essential features of the 54-unit doctoral core, providing coverage of the basics of the thermodynamic, kinetic, and properties of materials. These subjects offer adequate preparation for most of the department’s advanced graduate subjects.
During the fall term, students also participate in a subject that surveys materials engineering practice and take a course in materials selection, design, and economics. The course on engineering practice includes presentations by a large cross-section of the department faculty. During this first term, students and faculty also develop proposals for projects to be carried out as teams, either at a company site or on campus, in the spring (including January). Project proposals are reviewed and approved by a committee of faculty and non-faculty experts who also serve as a policy committee for the program. Projects are completed during the spring and summer terms.

In the fall or spring, students are also expected to take an advanced graduate subject from a set of restricted electives that focus on materials processing, as well as two elective graduate courses. For further information, see http://dmse.mit.edu/academics/graduate/.

Joint Program with the Leaders for Manufacturing Program
Students planning to apply their materials science and engineering education to a career in the manufacturing industry may apply for the Leaders for Manufacturing (LFM) program. The LFM program combines graduate education in materials science and engineering and management for those with two or more years of work experience who aspire to leadership positions in manufacturing or operations companies. This rigorous 24-month program combines subjects in technology and management. A required 6.5-month internship provides opportunity to complete a research project on site at one of LFM’s partner companies. The internship leads to a dual-degree thesis, culminating in two master’s degrees—an SM in management or an MBA, and an SM in engineering from the Department of Materials Science and Engineering. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description in the Engineering Systems Division section in Part 2 or visit http://lfm.mit.edu/.

Joint Program with the Technology and Policy Program
The Master of Science in Technology and Policy (TTP) is an engineering research degree with a strong focus on the role of technology in policy analysis and formulation. The Technology and Policy program (TTP) 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 TTP’s curriculum with complementary subjects to obtain dual degrees in TTP 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 in the Engineering Systems Division section in Part 2, or visit http://tppserver.mit.edu/.

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. 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 TTP’s curriculum with complementary subjects to obtain dual degrees in TTP 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 in the Engineering Systems Division section in Part 2, or visit http://tppserver.mit.edu/.

Requirements for Completion of Graduate Degrees
The general requirements for completion of graduate degrees are described in the section on Graduate Education in Part 1. 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 from the chairman of the Departmental Committee on Graduate Students.

Teaching and Research Assistantships
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 writing to the Student Services Office, Department of Materials Science and Engineering, Room 35-413, MIT, 617-253-3302.

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Thomas Maxisch,
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Chris Scott
George C. Whitfield
Xianglong Yuan

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Professor of Physical Metallurgy, Emeritus
Merton C. Flemings, ScD
Toyota Professor of Materials Processing, Emeritus
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Professor of Molecular Engineering and Electronic Materials, Emeritus
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Professor of Materials Science and Engineering
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Professor of Civil Engineering and Polymer Engineering, Emeritus
Walter Shepherd Owen, PhD
Professor of Physical Metallurgy, Emeritus
Mechanical engineering is concerned with the responsible development of products, processes, and power, whether at the molecular scale or at the scale of large, complex systems. Mechanical engineering principles and skills are needed at some stage during the conception, design, development, and manufacture of every human-made object with moving parts. Many innovations crucial to our future will have their roots in the world of mass, motion, forces, and energy—the world of mechanical engineers.

Mechanical engineering is one of the broadest and most versatile of the engineering professions. This is reflected in the portfolio of current activities in the department, one that has widened rapidly in the past decade. Today, our faculty are involved in projects ranging from, for example, the use of nanoparticles to tailor the properties of polymers, to the use of nonlinear dynamics to control unsteady flow separation; from the design and fabrication of low-cost radio-frequency identification chips, to the development of efficient methods for robust design; from the development of unmanned underwater vehicles, to the creation of optimization methods that autonomously generate decision-making strategies; from the invention of cost-effective photovoltaic cells, to the prevention of material degradation in proton-exchange membrane fuel cells; from the use of acoustics to explore the ocean of one of Jupiter’s moons, to the biomimetics of swimming fish; from the development of physiological models for the human liver, to the development of novel ways for detecting precancerous events; and from the use of nanoscale antennas for manipulating large molecules, to the fabrication of 3-D nanostructures out of 2-D substrates.

The department carries out its mission with a focus on the seven areas of excellence described below. Our education and research agendas are informed by these areas, and these are the areas in which we seek to impress the best undergraduate and graduate students.

**Area 1: Mechanics—Modeling, Experimentation, and Computation (MMEC).** At the heart of mechanical engineering lies the ability to measure, describe, and model the physical world of materials and mechanisms. The MMEC area focuses on teaching the fundamental principles, essential skills, and scientific tools to be able to predict and understand thermo-mechanical phenomena and use such knowledge in rational engineering design. We provide students with the foundations in experimental, modeling, and computational skills needed to understand, exploit, and enhance the thermo-physical behavior of advanced engineering devices and systems, and to make lifelong creative contributions at the forefront of the mechanical sciences and beyond. Research in the MMEC area focuses on four key thrusts:

- Computational mechanics
- Fluid dynamics
- Mechanics of solid materials
- Nonlinear dynamics

The fundamental engineering principles embodied in these topics can be applied over a vast range of force, time, and length scales, and applications of interest in the MMEC area span the spectrum from the nano/micro world to the geophysical domain. A Course 2-A track is offered in this area.

**Area 2: Product Realization.** Product realization is the complete set of activities needed to bring innovative new devices, technologies, and services to the marketplace. These activities extend across the entire product life cycle, from identification of a market opportunity, through product design, manufacturing, distribution, and end-of-life disposal. In a broad sense, product realization encompasses all of engineering. However, our activities are centered on synthesis—how creative engineering is used to produce new things to serve a practical purpose. The product realization group links new engineering methodologies, techniques, and processes with engineering activities in product development and manufacturing. Product realization requires deep disciplinary knowledge of mechanical engineering. For products to be competitive technically, they must incorporate appropriate new technologies and be refined using leading-edge modeling, simulation, and experimental methods. For products to be commercially competitive, they must be innovative, appropriate, elegantly designed, and manufactured in a globally competitive fashion. Many students come to MIT and mechanical engineering because they want to create new products. Having a group of faculty organized around product realization provides them with strong and coherent educational programs that will develop broad, deep, and versatile professionals and researchers in this area. A Course 2-A track in product realization is offered.

**Area 3: Control, Instrumentation, and Robotics.** The mission in this area is to promote research and education for automating, monitoring, and manipulating systems. The focus is on system-level behavior that emerges primarily from interactions and cannot be explained from individual component behavior alone. We seek to identify fundamental principles and methodologies that enable systems to exhibit intelligent, goal-oriented behavior, and develop innovative instruments to monitor, manipulate, and control systems. The core competencies in which we seek to excel are:

- Methodologies for understanding system behavior through physical modeling, identification, and estimation
- Technologies for sensors and sensor networks; actuators and energy transducers; and systems for monitoring, processing, and communicating information
- Fundamental theories and methodologies for analyzing, synthesizing, and controlling systems; learning and adapting to unknown environments; and effectively achieving task goals

We seek to apply our core competencies to diverse areas of social, national, and global needs. These include health care, security, education, space and ocean exploration, and autonomous systems in air, land, and underwater. We also offer a Course 2-A track in this area.

**Area 4: Energy Science and Engineering.** Energy is one of the most significant challenges facing humanity and is a central focus of mechanical engineering’s contribution to society. Our research focuses on efficient and environmentally friendly energy conversion and utilization from fossil and renewable resources. Programs in the department cover many of the disciplinary and technological aspects of energy, with applications to high performance combustion engines, batteries and fuel cells, thermoelectricity and photovoltaics, wind turbines, and efficient buildings. Work in very-low-temperature thermodynamics includes novel sub-Kelvin refrigeration and superconducting magnets. Efforts in high-temperature thermodynamics and its coupling with transport and chemistry
include internal combustion engine analysis, design, and technology; control of combustion dynamics and emissions; thermoelectric energy conversion; low- and high-temperature fuel cells; and novel materials for rechargeable batteries. Work in heat and mass transport covers thermal control of electronics from manufacturing to end use; microscale and nanoscale transport phenomena; high heat flux engineering; and energy-efficient building technology. Work in renewable energy encompasses the design of offshore and floating wind turbines and tidal wave machines; and analysis and manufacturing of photovoltaic and thermophotovoltaic devices. Energy storage, hybrid systems, fuel synthesis, and integration of energy systems are active research areas in the department. We also offer a Course 2-A undergraduate track in energy.

Area 5: Ocean Science and Engineering. The oceans cover over 70 percent of the planet’s surface and constitute a critical element in our quality of life, including the climate and the resources and food that we obtain from the sea. This area’s objectives are to support the undergraduate and graduate programs in ocean engineering, including the naval construction program, the MIT/Woods Hole Oceanographic Institution Joint Program in Applied Oceanography and the Course 2-0E track in ocean engineering. It also serves as the focus point of ocean-related research and education at MIT. Major current research activities include the robotics and navigation of underwater vehicles and smart sensors for ocean mapping and exploration; biomimetics to extract new understanding for the development of novel ocean systems studying marine animals; the study of the mechanics and fluid mechanics of systems for ultradepth ocean gas and oil extraction; ocean wave and offshore wind energy extraction; the free surface hydrodynamics of ocean-going vehicles; the development of advanced naval and commercial ships and submersibles, including the all-electric ship; the mechanics and crashworthiness of ocean ships and structures; ocean transportation systems; and ocean acoustics for communication, detection, and mapping in the ocean. The design of complex ocean systems permeates all these areas and provides the cohesive link for our research and teaching activities.

Area 6: Bioengineering. Engineering analysis, design, and synthesis are needed to understand biological processes and to harness them successfully for human use. Mechanical forces and structures play an essential role in governing the function of cells, tissues, and organs. Our research emphasizes integration of molecular-to-systems-level approaches to probe the behavior of natural biological systems; and to design and build new systems. At the smallest scale, proteins, enzymes, and biological motors are being studied using instrumentation that combines optical tweezers, single-molecule fluorescence, and pulsed spectroscopy. Single molecules are manipulated within complex systems using nanoscale antennas, opening new avenues for therapy and diagnosis. Computational and experimental models are used to describe the networks of molecules in the cytoskeleton, and how they couple with the extracellular matrix to respond to external forces. Emphasis is also placed on creating new physiological models using tools of nano- and microfabrication as well as creation of new biomaterials. Applications include understanding, diagnosing, and treating diseases ranging from atherosclerosis to osteoarthritis to liver failure; new tools for drug discovery and drug development; and tissue-engineered scaffolds and devices for in vivo regeneration of tissues and organs. Work also includes design and fabrication of new devices and tools for rehabilitation of stroke victims, and for robotic surgery. We offer many elective subjects as well as a bioengineering track in Course 2-A.

Area 7: Nano/Micro Science and Technology. The miniaturization of devices and systems of ever-increasing complexity has been a fascinating and productive engineering endeavor during the past few decades. Near and long term, this trend will be amplified as physical understanding of the nano world expands, and widespread commercial demand drives the application of manufacturing to micro- and nanosystems. Micro- and nanotechnology can have tremendous impact on a wide range of mechanical systems. Examples include microelectromechanical system (MEMS) devices and systems that are already deployed as automobile airbag sensors and for drug delivery; stronger and lighter nanostructured materials now used in automobiles; and nanostructured energy conversion devices that significantly improve the efficiency of macroscale energy systems. Research in this area cuts across mechanical engineering and other disciplines. Examples include sensors and actuators; fluidics, heat transfer, and energy conversion at the micro- and nanoscales; optical and biological micro- and nano-electromechanical systems (MEMS and NEMS); engineered 3-D nanomaterials; ultraprecision engineering; and the application of optics in measurement, sensing, and systems design. Our faculty members have developed and are developing new educational materials in micro and nano science and technology. Students interested in micro/nano technology are encouraged to explore the Course 2-A nano track.

In order to prepare the mechanical engineers of the future, the department has developed undergraduate and graduate educational programs of the depth and breadth necessary to address the diverse and rapidly changing technological challenges that society faces. Our educational programs combine the rigor of academic study with the excitement and creativity inherent to innovation and research.

Undergraduate Study

The Department of Mechanical Engineering offers three programs of undergraduate study. The first of these, the traditional program that leads to the bachelor’s degree in mechanical engineering, is a more structured program that prepares students for a broad range of career choices in the field of mechanical engineering. The second program leads to a bachelor’s degree in engineering and is intended for students whose career objectives require greater flexibility. It allows them to combine the essential elements of the traditional mechanical engineering program with study in another, complementary field. The third program, in mechanical and ocean engineering, is also a structured program for students interested in mechanical engineering as it applies to the engineering aspects of ocean science, exploration, and utilization, and of marine transportation.

All of the educational programs in the department prepare students for professional practice in an era of rapidly advancing technology. They combine a strong base in the engineering sciences (mechanics, materials, fluid and thermal sciences, systems and control) with
Bachelor of Science in Mechanical Engineering/Course 2

General Institute Requirements (GIRs)  
Subject 6  
Science Requirement  8  
Humanities, Arts, and Social Sciences Requirement  
Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 2.001 and 18.03 in the Departmental Program]  
Laboratory Requirement [can be satisfied by 2.671 in the Departmental Program]  
Total GIR Subjects Required for SB Degree 17

Communication Requirement  
The program includes a Communication Requirement of 4 subjects:  
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and  
2 subjects designated as Communication Intensive in the Major (CI-M) [satisfied by 2.009 and 2.671 in the Departmental Program].

PLUS Departmental Program  
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics).

Required Departmental Core Subjects  

<table>
<thead>
<tr>
<th>Subject Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.001 Mechanics and Materials I, 12, REST; 8.01, 18.02, 18.03</td>
<td>150</td>
</tr>
<tr>
<td>2.002 Mechanics and Materials II, 12; 2.001</td>
<td></td>
</tr>
<tr>
<td>2.003j Dynamics and Control I, 12, REST; 8.01, 18.03</td>
<td></td>
</tr>
<tr>
<td>2.004 Dynamics and Control II, 12; 2.003j, 8.02</td>
<td></td>
</tr>
<tr>
<td>2.005 Thermal-Fluids Engineering I, 12, REST; 8.02, 18.02, 18.03</td>
<td></td>
</tr>
<tr>
<td>2.006 Thermal-Fluids Engineering II, 12; 2.005, 18.03</td>
<td></td>
</tr>
<tr>
<td>2.007 Design and Manufacturing I, 12; 2.001, 2.670</td>
<td></td>
</tr>
<tr>
<td>2.008 Design and Manufacturing II, 12, 1/2 LAB; 2.002 or 2.012; 2.005; 2.007 or 2.017</td>
<td></td>
</tr>
</tbody>
</table>

Restricted Elective Subjects  
Students are required to take two of the following elective subjects (substitutions by petition to the ME Undergraduate Office):

<table>
<thead>
<tr>
<th>Subject Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.016 Hydrodynamics, 12; 8.02, 18.03</td>
<td>2009</td>
</tr>
<tr>
<td>2.017j Design of Systems Operating in Random Environments, 12; 2.003j, 2.016 or 2.005</td>
<td>2.009 The Product Engineering Process, 12, CI-M; 2.001, 2.003j, 2.005, 2.670</td>
</tr>
<tr>
<td>2.019 Design of Ocean Systems, 12, 1/2 LAB; 2.016 or 2.005; 2.671 or 6.071</td>
<td>2.670 Mechanical Engineering Tools, 6</td>
</tr>
<tr>
<td>2.06j Mechanical Vibration, 12; 2.003j</td>
<td>2.671 Measurement and Instrumentation, 12, LAB, CI-M; 2.001, 2.003j, 8.02</td>
</tr>
<tr>
<td>2.065 Acoustics and Sensing, 12; 2.003j, 6.003, 8.03, or 16.03</td>
<td>2.672 Project Laboratory, 6, 1/2 LAB; 2.001, 2.003j, 2.006, 2.671</td>
</tr>
<tr>
<td>2.092 Computer Methods in Dynamics, 12; 2.001, 2.003j</td>
<td>18.03 Differential Equations, 12, REST; 18.02*</td>
</tr>
<tr>
<td>2.111 Introduction to Robotics, 12; 1.204</td>
<td>2.01 Independent Study or Thesis, 6(1)</td>
</tr>
<tr>
<td>2.112 Analysis and Design of Feedback Control Systems, 12; 2.004</td>
<td></td>
</tr>
<tr>
<td>2.370 Molecular Mechanics, 12; 2.001; 3.091, 5.111, or 5.112; 8.01</td>
<td>2.371 Microscale Fluid Mechanics, 12; 2.005, 8.02</td>
</tr>
<tr>
<td>2.41 Advanced Thermal Fluids Engineering, 12; 2.066</td>
<td>2.51 Intermediate Heat and Mass Transfer, 12; 2.006*</td>
</tr>
<tr>
<td>2.60 Fundamentals of Advanced Energy Conversion, 12; 2.066*</td>
<td>2.71 Optics, 12; 2.004, 8.02, 18.03*</td>
</tr>
<tr>
<td>2.72 Elements of Mechanical Design, 12; 2.005, 2.007, 2.671</td>
<td>2.737 Molecular, Cellular, and Tissue Biomechanics, 12; 18.03 or 3.016; 7.012; 2.370 or 2.772*</td>
</tr>
<tr>
<td>2.96 Management in Engineering, 12</td>
<td></td>
</tr>
</tbody>
</table>

Departmental Program Units That also Satisfy the GIRs  
(36)  
Unrestricted Electives  
(48)  
Total Units Beyond the GIRs Required for SB Degree 186

No subject can be counted both as part of the 17-subject GIRs and as part of the 186 units required beyond the GIRs. Every subject in the student's departmental program will count toward one or the other, but not both.

Notes:
(1) Alternate prerequisites are listed in the subject description.
(2) To encourage more substantial research, design, or independent study, the department permits up to 15 units of a Thesis credit, subject to approval of the student's faculty advisor.
(3) The department suggests that students elect an introductory digital-computing subject (e.g., 1.00) as early as possible in their program, and a basic electronics subject (e.g., 6.002 or 6.071).

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

Bachelor of Science in Engineering as Recommended by the Department of Mechanical Engineering/Course 2-A  
Course 2-A is designed for students whose academic and career goals demand greater breadth and flexibility than are allowed under the mechanical engineering program, Course 2. To a large extent, the 2-A program allows students an opportunity to tailor a curriculum to project-based laboratory and design experiences. All strive to develop independence, creative talent, and leadership, as well as the capability for continuing professional growth.
their own needs, starting from a solid mechanical engineering base. The program combines a rigorous grounding in core mechanical engineering subjects with an individualized course of study focused on a second area that the student designs with the help and approval of the 2-A faculty advisor. The program leads to the Bachelor of Science degree in Engineering as recommended by the Department of Mechanical Engineering. This degree is accredited by the Accreditation Board for Engineering and Technology.

The educational objectives of the program leading to the degree Bachelor of Science in Engineering as Recommended by the Department of Mechanical Engineering are that: (1) students will develop a solid foundation in basic mathematical and scientific knowledge and in the basic principles and disciplines of mechanical engineering; (2) students will be able to model, measure, analyze, and design engineering systems, processes, and components using proper engineering principles; (3) students will have the professional skills necessary for formulating and executing design projects, for teamwork, and for effective communication; (4) students will develop the confidence, societal context, ethics, and motivation for lifelong learning that will equip them to be leaders in their chosen fields of endeavor; and (5) students will have an education that prepares them to integrate mechanical engineering technical abilities and knowledge with those of another disciplinary field.

A significant part of the 2-A curriculum consists of electives chosen by the student to provide in-depth study of a field of the student’s choosing. A wide variety of popular concentrations are possible in which well-selected academic subjects complement a foundation in mechanical engineering and general Institute requirements. Some examples of potential concentrations include biomedical engineering and pre-medicine; energy conversion engineering; engineering management; product development; robotics; technology policy and pre-law; sustainable design and engineering; architecture and building technology; and any of the seven departmental focus areas mentioned above. The ME faculty have developed specific recommendations in some of these areas; details are available from the ME Undergraduate Office.

### Bachelor of Science as Recommended by the Department of Mechanical Engineering/Course 2-A

#### General Institute Requirements (GIRs)

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Science Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Humanities, Arts, and Social Sciences Requirement</td>
</tr>
<tr>
<td></td>
<td>Restricted Electives in Science and Technology (REST) Requirement (can be satisfied by 2.001 and 18.03 in the Departmental Program)</td>
</tr>
<tr>
<td></td>
<td>Laboratory Requirement (satisfied by 2.671 in the Departmental Program)</td>
</tr>
</tbody>
</table>

#### Total GIR Subjects Required for SB Degree

17

#### Communication Requirement

2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and 2 subjects designated as Communication Intensive in the Major (CI-M) [satisfied by 2.009 and 2.671 in the Departmental Program].

#### PLUS Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics).

<table>
<thead>
<tr>
<th>Required Departmental Core Subjects</th>
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</tr>
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<tbody>
<tr>
<td>2.001 Mechanics and Materials I, 12, REST; 8.01, 18.02, 18.03</td>
<td>78</td>
</tr>
<tr>
<td>2.003J Dynamics and Control I, 12, REST; 8.01, 18.03</td>
<td></td>
</tr>
<tr>
<td>2.005 Thermal-Fluids Engineering I, 12, REST; 8.02, 18.02, 18.03</td>
<td></td>
</tr>
<tr>
<td>2.009 The Product Engineering Process, 12, CI-M; 2.001, 2.003J, 2.005, 2.670</td>
<td></td>
</tr>
<tr>
<td>2.670 Mechanical Engineering Tools</td>
<td></td>
</tr>
<tr>
<td>2.671 Measurement and Instrumentation, 12, LAB, CI-M; 2.001, 2.003J, 8.02</td>
<td></td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; 18.02*</td>
<td></td>
</tr>
</tbody>
</table>

#### Three of Five Mechanical Engineering Core Subjects

Students may petition to replace one of these three subjects with a subject on the Course 2 Restricted elective list (file petition at the ME Undergraduate Office).

| 2.002 Mechanics and Materials II, 12; 2.001 | |
| 2.004 Dynamics and Control II, 12; 2.003J, 8.02 | |
| 2.006 Thermal-Fluids Engineering II, 12; 2.005, 18.03 | |
| 2.007 Design and Manufacturing I, 12; 2.001, 2.670 | |
| 2.008 Design and Manufacturing II, 12, 1/2 LAB; 2.002 or 2.012; 2.005; 2.007 or 2.017 | |

#### Elective Subjects with Engineering Content(1)

60

#### Departmental Program Units That also Satisfy the GIRs

(36)

#### Unrestricted Electives

48

#### Total Units Beyond the GIRs Required for SB Degree

186

No subject can be counted both as part of the 17-subject GIRs and as part of the 186 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

### Notes

1) These electives define a concentrated area of study and must be chosen with the written approval of the ME Undergraduate Office. A minimum of 15 units of engineering topics must be included in the 60 units of concentration electives. Engineering topics are usually obtained from engineering courses, but in some cases, non-engineering subjects may be necessary for the particular engineering program defined by the concentration (e.g., biology or chemistry for a bioengineering concentration). In all cases, the relationship of concentration subjects to the theme of the concentration must be obvious. A thesis (2.ThU) of up to 12 units may be included among the concentration electives.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
Bachelor of Science In Mechanical and Ocean Engineering/Course 2-OE

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 2.001 and 18.03 in the Departmental Program]</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement [can be satisfied by 2.671 in the Departmental Program]</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

Communication Requirement
The program includes a Communication Requirement of 4 subjects:
- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H), and 2 subjects designated as Communication Intensive in the Major (CI-M) (satisfied by 2.019 and 2.671 in the Departmental Program).

PLUS Departmental Program
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics).

### Required Departmental Subjects

<table>
<thead>
<tr>
<th>Subject Name</th>
<th>Units</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.005 Mechanics and Materials I</td>
<td>12</td>
<td>REST, 8.01, 18.02, 18.03</td>
</tr>
<tr>
<td>2.005 Dynamics and Control I</td>
<td>12</td>
<td>REST, 8.01, 18.03</td>
</tr>
<tr>
<td>2.004</td>
<td>12</td>
<td>2.003J, 8.02</td>
</tr>
<tr>
<td>2.004</td>
<td>12</td>
<td>2.003J, 8.02, 18.03</td>
</tr>
<tr>
<td>2.008 Design and Manufacturing I</td>
<td>12</td>
<td>2.002 or 2.012, 2.005; 2.007 or 2.007J</td>
</tr>
<tr>
<td>2.012</td>
<td>12</td>
<td>2.001 or 1.050</td>
</tr>
<tr>
<td>2.016 Hydrodynamics</td>
<td>12</td>
<td>2.002, 18.03</td>
</tr>
<tr>
<td>2.017</td>
<td>12</td>
<td>2.005</td>
</tr>
<tr>
<td>2.019 Design of Ocean Systems</td>
<td>12</td>
<td>2.005 or 2.005; 2.671 or 6.071</td>
</tr>
<tr>
<td>2.612 Marine Power and Propulsion</td>
<td>12</td>
<td>2.005</td>
</tr>
<tr>
<td>2.670 Mechanical Engineering Tools</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>2.671 Measurement and Instrumentation</td>
<td>12</td>
<td>LAB, CI-M; 2.001, 2.003J, 8.02</td>
</tr>
<tr>
<td>18.03 Differential Equations</td>
<td>12</td>
<td>REST, 18.02*</td>
</tr>
</tbody>
</table>

### Restricted Elective Subjects
Students are required to take two of the following elective subjects (substitutions by petition to the ME Undergraduate Office):

<table>
<thead>
<tr>
<th>Subject Name</th>
<th>Units</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.005 Thermal Fluids Engineering I</td>
<td>12</td>
<td>2.005</td>
</tr>
<tr>
<td>2.007 Design and Manufacturing I</td>
<td>12</td>
<td>2.001, 2.670</td>
</tr>
<tr>
<td>2.051 Mechanical Vibration</td>
<td>12</td>
<td>2.003J</td>
</tr>
<tr>
<td>2.068 Advanced Structural Dynamics</td>
<td>12</td>
<td>2.080, 18.03</td>
</tr>
<tr>
<td>2.085 Acoustics and Sensing</td>
<td>12</td>
<td>2.003J, 6.003, 8.03, or 16.03</td>
</tr>
<tr>
<td>2.085 Structural Mechanics</td>
<td>12</td>
<td>2.002 or 2.012</td>
</tr>
<tr>
<td>2.092 Computer Methods in Dynamics</td>
<td>12</td>
<td>2.001, 2.003J</td>
</tr>
<tr>
<td>2.149 Analysis of Feedback Control Systems</td>
<td>12</td>
<td>2.004</td>
</tr>
<tr>
<td>2.206 Marine Hydrodynamics</td>
<td>12</td>
<td>2.006, 2.016, or 1.060</td>
</tr>
<tr>
<td>2.410 Advanced Thermal Fluids Engineering</td>
<td>12</td>
<td>2.006</td>
</tr>
<tr>
<td>2.51 Intermediate Heat and Mass Transfer</td>
<td>12</td>
<td>2.006*</td>
</tr>
<tr>
<td>2.60 Fundamentals of Advanced Energy Conversion</td>
<td>12</td>
<td>2.006*</td>
</tr>
<tr>
<td>2.705 Introduction to Naval Architecture</td>
<td>12</td>
<td>2.002 or 2.012</td>
</tr>
<tr>
<td>2.72 Elements of Mechanical Design</td>
<td>12</td>
<td>2.005, 2.007, 2.671</td>
</tr>
<tr>
<td>2.76 Marine Vibration</td>
<td>12</td>
<td>2.705</td>
</tr>
<tr>
<td>2.95 Management in Engineering</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td><strong>THU Undergraduate Thesis</strong></td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

### Departmental Program Units That also Satisfy the GIRs

<table>
<thead>
<tr>
<th>Subject Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(36)</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Unrestricted Electives

<table>
<thead>
<tr>
<th>Subject Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>48</strong></td>
<td></td>
</tr>
</tbody>
</table>

Total Units Beyond the GIRs Required for SB Degree: 186

No subject can be counted both as part of the 17-subject GIRs and as part of the 186 units required beyond the GIRs. Every subject in the student's Departmental Program will count toward one or the other, but not both.

### Notes

*Alternate prerequisites are listed in the subject description.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

Concentrations are not limited to those listed above. Students are encouraged to design and propose technically oriented concentrations that reflect their own needs and those of society.

The student’s overall program must contain a total of at least one and one-half years of engineering-topics content (144 units) appropriate to the student’s field of study. The required core and second-level subjects include approximately 93 units of engineering topics. The self-designed concentration must include at least 51 more units of engineering topics. While engineering topics are usually covered through engineering subjects, non-engineering subjects may provide material essential to the engineering program of some concentrations. For example, biology and chemistry subjects usually form an essential part of a bioengineering concentration. In all cases, the relationship of concentration subjects to the particular theme of the concentration must be obvious. A thesis (2.THU) of up to 12 units may be included in the concentration, if desired.

Students who wish to pursue this degree must advise the department’s Undergraduate Office during their sophomore year to allow enough time to plan a complete program. Registration for this degree program requires approval in writing from the ME Undergraduate Office. Registration forms are available in the ME Undergraduate Office, and should be submitted within one term of entering Course 2-A.

### Bachelor of Science in Mechanical and Ocean Engineering/Course 2-OE

This program is designed for students interested in mechanical engineering with specialization in ocean engineering, including engineering aspects of the ocean sciences, ocean exploration, and utilization of the oceans for transportation, defense, and resources. The program leads to the Bachelor of Science in Mechanical and Ocean Engineering. Graduates are prepared for work in industry or government, or for further study in graduate school.

The educational objectives of the program leading to the degree Bachelor of Science in Mechanical and Ocean Engineering are that: (i) students will develop a solid foundation in basic mathematical and scientific knowledge and in the fundamental principles and disciplines of both mechanical and ocean engineering;
(2) students will be able to model, measure, analyze, and design mechanical, thermal, and ocean components and systems using proper engineering principles; (3) students will have the professional skills necessary for formulating and executing design projects, for teamwork, and for effective communication; and (4) students will develop the confidence, societal context, ethics, and motivation for lifelong learning that will equip them to be leaders in their chosen fields of endeavor.

The School of Engineering intends to seek accreditation for this curriculum. Accreditation is expected to be retroactive for the first students graduating with this degree.

Undergraduate Practice Opportunities Program
The Undergraduate Practice Opportunities Program is a program sponsored by the School of Engineering and administered through the Office of the Dean of Engineering. Further information on the program may be obtained from the department in which the student is registered or from Christopher Resto, director, Undergraduate Practice Opportunities Program, Room 12-188, MIT, 617-452-5099, fax 617-253-8457, email cresto@mit.edu, or http://web.mit.edu/engineering/upop/.

Minor in Mechanical Engineering
The requirements for a Minor in Mechanical Engineering are as follows:

Students pursuing a minor in the department must complete a total of six subjects (including 18.03 as a prerequisite to departmental subjects). Subjects for the minor must constitute a coherent program approved by the department, and be drawn from the required subjects and departmental electives in the Course 2 or Course 2-OE degree programs. These subjects must include completion of two of the ME program’s four core sequences.

Inquiries
Further information on undergraduate programs may be obtained from the Undergraduate Office, Room 1-110, MIT, 617-253-2305, or by email to me-undergradoffice@mit.edu.

GRADUATE STUDY
The Mechanical Engineering Department provides opportunities for graduate work leading to the following degrees: Master of Science in Mechanical Engineering, Master of Science in Ocean Engineering, Master of Science in Naval Architecture and Marine Engineering, Master of Science without specification of department, Master of Engineering in Manufacturing, degree of Mechanical Engineer, degree of Naval Engineer, and the Doctor of Philosophy (PhD) or Doctor of Science (ScD), which differ in name only.

Most master’s degree students register for one of the three degrees with a specification in engineering. Some students may forego specification in order to have more freedom in the selection of subjects. The various master’s degrees all have equal academic stature.

The Master of Engineering degree is a twelve-month professional degree intended to prepare students for technical leadership in the manufacturing industries.

The Mechanical Engineer’s and Naval Engineer’s degrees offer preparation for a career in advanced engineering practice through a program of advanced coursework that goes well beyond the master’s level. These degrees are not a stepping stone to the PhD.

The Doctor of Philosophy (or Science), the highest academic degree offered, is awarded upon the completion of a program of advanced study and significant original research, design, or development.

Entrance Requirements for Graduate Study
Applications to the Mechanical Engineering Graduate School are accepted from persons who have completed, or will have completed by the time they arrive, a bachelor’s degree. Most incoming students have a degree in mechanical engineering or ocean engineering, or some related branch of engineering. The department’s admission criteria are not specific, however, and capable students with backgrounds in different branches of engineering or in science may gain entry. Nevertheless, to qualify for a graduate degree other than the master’s without specification, the candidate is expected to have had at least an undergraduate-level exposure to the core subject areas in mechanical engineering (applied mechanics, dynamics, fluid mechanics, thermodynamics, materials, control systems, and design) and to be familiar with basic electrical circuits and electromagnetic field theory. Those with deficiencies may be asked to make up subjects in certain areas before they graduate.

Applications for September entry are due on December 15 of the previous year, and decisions are reported in March. Foreign students applying from abroad may be admitted, but they will be allowed to register only if they have full financial support for the first year.

All applicants to the graduate program in mechanical engineering must submit the GRE test results. Students applying from non-English-speaking countries are required to take the Test of English as a Foreign Language (TOEFL) and receive a minimum paper-based score of 577 or a minimum computer-based score of 233.

Early Admission to Master’s Degree Programs in Mechanical Engineering
At the end of the junior year, extraordinarily qualified students in the Department of Mechanical Engineering will be invited to apply for early admission to the graduate program. Students who are admitted will then be able to enroll in core graduate subjects during the senior year and to find a faculty advisor who is willing to start and supervise research for the master’s thesis while the student is still in the senior year. With the consent of the faculty advisor, the student may also use a portion of the work conducted towards the master’s thesis in the senior undergraduate year to satisfy the requirements of the bachelor’s thesis.

Writing Ability Requirement
The Mechanical Engineering Department requires that all incoming graduate students demonstrate satisfactory English writing ability, or successfully complete appropriate training in writing. This requirement reflects the faculty’s conviction that writing is an essential skill for all engineers. All incoming graduate students, native as well as foreign, must take the departmental writing ability test, which is administered in September. Depending on the results, a student will either pass or be required to take a subject in writing.
Master of Science in Mechanical Engineering

To qualify for the Master of Science in Mechanical Engineering, a student must complete at least 72 credits of coursework. Of these, at least 42 must be graduate H-level subjects designated as such in Part 3. The remainder of the 72 units may be for G-level subjects or advanced undergraduate subjects that are not requirements in the undergraduate Mechanical Engineering curriculum.

At least two of the subjects must be chosen from a prescribed list of basic mechanical engineering sciences. The student must also either have had previously, or take as part of his or her master’s program, two advanced mathematics subjects (e.g., 18.085 and 18.086).

Finally, a thesis is required. The thesis is an original work of research, development, or design, performed under the supervision of a faculty or research staff member, and is a major part of any graduate program in the Mechanical Engineering Department. A master’s student usually spends as much time on thesis work as on coursework. A master’s degree usually takes about one and one-half to two years to complete.

Master of Science in Ocean Engineering/
Master of Science in Naval Architecture and Marine Engineering

The curriculum leading to a Master of Science in Ocean Engineering is based on a broad working knowledge of all the basic engineering skills. The intended outcome of this program is a person whose main interest is the development of the ocean for the good of humanity, and who, in following this ambition, is prepared to use whatever engineering disciplines are needed to address the problem at hand.

As a part of the more general field of ocean engineering, naval architecture and marine engineering are concerned with all aspects of waterborne vehicles operating on, below, or just above the sea surface. The Master of Science in Naval Architecture and Marine Engineering is intended to develop an individual who plans to concentrate in areas related to waterborne vehicles and/or their subsytems.

The requirements for these degrees are that the student take 72 credit units of subjects—with 48 of them being H-level subjects—and complete a thesis. At least three of the subjects must be chosen from a prescribed list of basic ocean engineering subjects. The student must also have had previously, or take as part of his or her master’s program, an advanced mathematics subject (e.g., 18.085) and a computation-related subject.

Master of Science (without Specification)

The requirements for the Master of Science without specification are that the student take 72 credit units of subjects—with 42 of them being H-level subjects—and complete a thesis. These are the minimum requirements for an MS degree at MIT. The degree without specification and the degree with specification have equal academic stature. The degree without specification does not, however, explicitly confer an association with the mechanical engineering profession, though such an association may be inferred from the student’s having been registered in the Department of Mechanical Engineering.

Students who opt for the degree without specification usually have in mind specific programs of study with which they cannot meet all the requirements of the degrees with specification in the time they have available.

Master of Science in Manufacturing

The Master of Science in Manufacturing is a 12-month professional degree in mechanical engineering that is intended to prepare the student to assume a role of technical leadership in the manufacturing industries. The degree is aimed at practitioners who will use this knowledge to become leaders in existing, as well emerging, manufacturing companies. To qualify for this degree, a student must complete a highly integrated set of subjects and projects that cover the process, product, system, and business aspects of manufacturing, totaling 90 units, plus complete a group-based thesis project. While centered in engineering and firmly grounded in the engineering sciences, this degree program is centered on the enterprise of manufacturing. Students will gain both a broad understanding of the many facets of manufacturing and a knowledge of manufacturing fundamentals from which to build new technologies and businesses. The admission process is identical to that of the Master of Science degree, with the exception that a supplemental application is required. For more information, see the program description at http://web.mit.edu/~meng-manufacturing/.

Leaders for Manufacturing Program

The Leaders for Manufacturing (LFM) program combines graduate education in engineering and management for those with two or more years of work experience who aspire to leadership positions in manufacturing or operations companies. This rigorous 24-month program combines subjects in technology and management. A required 6.5-month internship provides opportunity to complete a research project on site at one of LFM’s partner companies. The internship leads to a dual-degree thesis, culminating in two master’s degrees—an SM in management or an MBA, and an SM in engineering from the Department of Mechanical Engineering. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description in the Engineering Systems Division section in Part 2 or visit http://lfm.mit.edu/.

Mechanical Engineer’s Degree

The Mechanical Engineer’s degree provides an opportunity for further study beyond the master’s level for those who wish to enter engineering practice rather than research. This degree emphasizes breadth of knowledge in mechanical engineering and its economic and social implications, and is quite distinct from the PhD, which emphasizes depth and originality of research.

The engineer’s degree requires a broad program of advanced coursework in mechanical engineering totaling at least 162 credit units (typically about 14 subjects), including those taken during the master’s degree program. The engineer’s degree program is centered around the application of engineering principles to advanced engineering problems and includes an applications-oriented thesis, which may be an extension of a suitable master’s thesis. An engineer’s degree typically requires at least one year of study beyond the master’s degree.

Naval Engineer’s Degree—Program in Naval Construction and Engineering

The program leading to the Naval Engineer’s degree requires a higher level and significantly broader range of professional competence in engineering than is required for an SM in naval architecture and marine engineering or ocean engineering. The program for an engineer’s
degree ordinarily includes subjects in the areas of economics, industrial management, and public policy or law, and at least 12 units of comprehensive design. Should the student be working toward the simultaneous award of the engineer’s and master’s degrees, a single thesis is generally acceptable provided it is appropriate to the specifications of both degrees and demonstrates the educational maturity expected of candidates for the higher degree.

The Naval Construction and Engineering (NCE) program provides US Navy and US Coast Guard officers, foreign naval officers, and civilian students interested in ships and ship design a broad graduate-level engineering education for a career as a professional naval engineer. The program focuses on naval architecture, hydrodynamics, ship structures, materials, power and propulsion, and ship production in a total-ship-design and engineering context. Students learn to apply a total-system-design approach to large-scale complex systems—in particular, surface naval combatants, submarines, and high-performance commercial ships. The program is appropriate for naval officers and civilians who later actively participate in concept formulation, design, and construction of naval ships, as well as for those interested in commercial ship design. In addition to general engineering and science and a core program of subjects in ocean engineering, each student follows one of several specialized curricula applicable to ship construction and engineering.

**Doctor of Philosophy and Doctor of Science**

The highest academic degree is the Doctor of Science, or Doctor of Philosophy (the two differ only in name). This degree is awarded upon the completion of a program of advanced study, and the performance of significant original research, design, or development. Doctoral degrees are offered in all areas represented by the department’s faculty.

Students become candidates for the doctorate by passing a rigorous qualifying examination. The doctoral program includes a major program of advanced study in the student’s principal area of interest, and a minor program of study in a different field. The Graduate Office should be consulted about the deadline for passing the qualifying exam.

The principal component of the program is the thesis. The thesis is a major, original work that makes a significant research, development, or design contribution in its field. The thesis and the program of study are done under a faculty supervisor and a doctoral committee selected by the student and his or her supervisor, and perhaps other interested faculty members. The committee makes an annual examination of the candidate’s progress and conducts a final examination based on the thesis. The doctoral program usually takes a minimum of two years of work beyond the master’s degree.

**Interdisciplinary Programs**

Graduate students registered in the Department of Mechanical Engineering may elect to participate in interdisciplinary programs of study. Programs are available in computation for design and optimization, health sciences and technology, polymer science and technology, and technology and policy. See Interdisciplinary Graduate Programs in Part 2 for program descriptions.

**Joint Program with the Woods Hole Oceanographic Institution**

The Joint Program with the Woods Hole Oceanographic Institution (2W) is intended for students whose primary career objective is oceanographic engineering. Students divide their academic and research efforts between the campuses of MIT and WHOI. Joint Program students are assigned an MIT faculty member as academic advisor; however, thesis research may be supervised by MIT or WHOI faculty. While in residence at MIT, students follow a program similar to that of other students in the department. The program is described in more detail at the end of Part 2 of this bulletin.

**Assistantships and Fellowships**

The Department of Mechanical Engineering offers three types of financial assistance to graduate students: research assistantships, teaching assistantships, and fellowships.

The majority of students in the department are supported by research assistantships (RAs), which are appointments to work on particular research projects with particular faculty members. Faculty members procure research grants for various projects and hire graduate students to carry out the research. The research is almost invariably structured so that it becomes the student’s thesis. An RA appointment provides a full-tuition scholarship (i.e., covers all tuition) plus a salary that is adequate for a single person. The financial details are outlined in a separate handout available from the Departmental Graduate Office. An RA may register for a maximum of 24 units (about two subjects) of classroom subjects per regular term and 12 units in the summer term, and must do at least the equivalent of 24 units of thesis (i.e., research on the project) per term.

Teaching assistants (TAs) are appointed to work on specific subjects of instruction. As the name implies, they usually assist a faculty member in teaching, often grading homework problems and tutoring students. In the Mechanical Engineering Department, TAs are very seldom used for regular full-time classroom teaching. TAs are limited to 24 units of credit per regular term, including both classroom subjects and thesis. The TA appointment does not usually extend through the summer.

A fellowship provides the student with a direct grant, and leaves the student open to select his or her own research project and supervisor. A limited number of awards and scholarships are available to graduate students directly through the department. A number of students are also supported by fellowships from outside agencies, such as the National Science Foundation, Office of Naval Research, and Department of Defense. Scholarships are awarded each year by the Society of Naval Architects and Marine Engineers. These awards are normally granted to applicants whose interest is focused on naval architecture and marine engineering or on ocean engineering. Applications are made directly to the granting agency, and inquiries for the fall term should be made in the preceding fall term.

Prospective students are invited to communicate with the department regarding any of these educational and financial opportunities.

Experience has shown that the optimum graduate program consists of about equal measures of coursework and research, consistent with an RA appointment. The main advantage of a fellowship is a greater freedom in choosing a research project and supervisor. A teaching assistantship gives the student teaching experience and can also be extremely valuable for
reviewing basic subject material—for example, in preparation for the doctoral general exams. It does not, however, leave much time for thesis research and may extend the time that the student needs to complete his or her degree.

Inquiries
For additional information, contact Leslie Regan, Mechanical Engineering Graduate Registration Office, Room 1-112, MIT, 617-253-2291, or by email to me-gradoffice@mit.edu.

RESEARCH LABORATORIES AND PROGRAMS

The Mechanical Engineering Department is organized into seven areas that collectively capture the broad range of interests and activities within it. These areas are:

- Mechanics: Modeling, Experimentation, and Computation
- Product Realization
- Control, Instrumentation, and Robotics
- Energy Science and Engineering
- Ocean Science and Engineering
- Bioengineering
- Nano/Micro Science and Technology

The educational opportunities offered to students in mechanical engineering are enhanced by the availability of a wide variety of research laboratories and programs, and well-equipped shops and computer facilities.

The department provides many opportunities for undergraduates to establish a close relationship with faculty members and their research groups. Students interested in project work are encouraged to consult their faculty advisor or approach other members of the faculty.

Many members of the Department of Mechanical Engineering participate in interdepartmental or school-wide research activities. These include the Biotechnology Process Engineering Center, Center for Biomedical Engineering, Center for Materials Science and Engineering, Computational and Systems Biology Program, Computer Science and Artificial Intelligence Laboratory, Institute for Soldier Nanotechnologies, Laboratory for Energy and the Environment, Laboratory for Manufacturing and Productivity, Operations Research Center, Program in Polymer Science and Technology, and Sea Grant College Program. Detailed information about each of these can be found in the section on Interdisciplinary Research and Study in Part 1. The department also hosts a number of industrial consortia, which support some laboratories and research projects. Research in the department is supported, in addition, by a broad range of federal agencies and foundations.

Below is a partial list of departmental laboratories, listed according to the seven core areas of research.

Mechanics: Modeling, Experimentation, and Computation

AMP Mechanical Behavior of Materials Laboratory
Mechanisms of deformation and fracture processes in engineering materials.

Center for Nonlinear Science
Interdisciplinary research into nonlinear phenomena. Incorporates the Nonlinear Dynamical Systems Lab (modeling, simulation, analysis), Nonlinear Dynamics Lab (experiments), and Nonlinear Systems Lab.

Composite Materials and Nondestructive Evaluation Laboratory
Development of quantitative nondestructive evaluation characterizations which are directly correlatable with the mechanical properties of materials and structures.

Finite Element Research Group
Computational procedures for the solution of problems in structural, solid, and fluid mechanics.

Hatsopoulos Microfluids Laboratory
Fundamental research on the behavior of fluid systems at microscopic scales, and the engineering applications that accrue from it.

Product Realization

Computer-Aided Design Laboratory
Advancing the state of the art in design methodology and computer-aided design methods.

Laboratory for Manufacturing and Productivity
Analysis and design of manufacturing processes, systems, and products. Current activities include precision machine design, 3-D printing, droplet-based manufacturing, discrete dies, axiomatic design, auto-ID, casting monitoring, systems analysis and design, tribology, MEMS, and environmentally benign manufacturing.

Martin Center for Engineering Design
Design methodology, design of integrated electrical-mechanical systems, prototype development, advanced computer-aided design techniques.

Park Center for Complex Systems
Research to understand complexity, educating students and scholars on complexity, designing complex systems for the benefit of humankind, and disseminating knowledge on complexity to the world at large.

Precision Engineering Laboratory
Fundamental and applied research on all aspects of the design, manufacture, and control of high precision machines ranging from manufacturing machines to precision consumer products.

Precision Systems Design and Manufacturing
Modeling, design, and manufacturing methods for nanopositioning equipment, carbon nanotube-based mechanisms and machines, and compliant mechanisms.

Control, Instrumentation, and Robotics

Auto-ID Laboratory
Creation of the “Internet of Things” using radio frequency identification and wireless sensor networks, and of a global system for tracking goods using a single numbering system called the Electronic Product Code.

d’Arbeloff Laboratory for Information Systems and Technology
Research on mechatronics, home and health automation, interface between hardware and software, and development of sensing technologies.
Field and Space Robotics Laboratory
Fundamental physics of robotic systems for unstructured environments. Development, design, and prototyping of control and planning algorithms for robotic applications, including space exploration, rough terrains, sea systems, and medical devices and systems.

Nonlinear Systems Laboratory
Analysis and control of nonlinear physical systems with emphasis on adaptation and learning in robots.

Energy Science and Engineering
Center for 21st-Century Energy
Innovative science and technology for a sustainable energy future. Fundamental research in transport phenomena and thermodynamics; applied research in energy conversion, transportation, and thermal management. Draws upon activities in several of the department’s laboratories.

Cryogenic Engineering Laboratory
Application of thermodynamics, heat transfer, and mechanical design to cryogenic processes and apparatus and the operation of a liquid helium facility.

Electrochemical Energy Laboratory
Engineering of advanced materials for lithium batteries, proton exchange membrane and solid oxide fuel cells, and air battery and fuel cell hybrids.

Fuel Cell Laboratory
Innovation in the design of fuel cells and in the application of fuel cell technology for energy conversion in stationary and portable power plants.

Reacting Gas Dynamics Laboratory
Fluid flow, chemical reaction, and combustion phenomena associated with energy conversion in propulsion systems, power generation, industrial processes, and fires.

Rohsenow Heat and Mass Transfer Laboratory
Fundamental research in convection, microscale/nanoscale transport, laser/material interaction, sprays, and high heat fluxes; applied research in materials processing, fluidized bed combustors, energy-efficient buildings, and thermal management of electronics.

Sloan Automotive Laboratory
Processes and technology that control the performance, efficiency, and environmental impact of internal combustion engines, their lubrication, and fuel requirements.

Ocean Science and Engineering
Center for Ocean Engineering
Provides an enduring ocean engineering identity, giving visibility to the outside world of MIT’s commitment to the oceans, and serves as the focus point of ocean-related research at the Institute. Supports the research activities of the MIT/WHOI Joint Program in Oceanographic Engineering and the Naval Construction and Engineering Program. Encompasses the activities of the following research groups and laboratories:

  Acoustics Group: Research in ocean acoustics, acoustic sensing for naval applications, fisheries, ocean exploration and mapping, ocean observation systems, signal processing, and detection in the underwater environment.

  Design Laboratory: Research in biomimetics, robotics, naval architecture, ship and offshore structure design, computer-aided design and manufacturing, geometric modeling and computer visualization, distributed systems for ocean forecasting, adaptive ocean sampling methodologies, cable and riser dynamics and design, and marine transportation. Affiliated with the MIT Sea Grant Autonomous Underwater Vehicles Lab.

  Hydraulics Group: Includes the Marine Hydrodynamics Laboratory (Propeller Tunnel) and the Testing Tank Facility (Towing Tank); the Vertical Flow Research Laboratory; the Laboratory for Ship and Platform Flows; and the Marine Computation and Instrumentation Laboratory. Research areas include experimental fluid mechanics, vortex-induced hydrodynamic loads, seakeeping, maneuvering and control, computational fluid dynamics, hydrodynamic load prediction, performance evaluation of ocean vehicles, wave-field analysis and prediction, propulsor system design, marine robotics, biomimetics, air-sea interaction, and advanced sailing-boat design.

  Structural Mechanics and Dynamics Group: Includes the Impact and Crashworthiness Laboratory, with emphasis on structural mechanics of large complex structures, impact loads and weapon effects on structures, and crashworthiness.

  Structural Dynamics Laboratory: Emphasis on vortex induced vibrations and riser dynamics.

Bioengineering

Bioinstrumentation Laboratory
Utilization of biology, optics, mechanics, mathematics, electronics, and chemistry to develop innovative instruments for the analysis of biological processes and new devices for the treatment and diagnosis of disease.

Human and Machine Haptics
Interdisciplinary studies aimed at understanding human haptics, developing machine haptics, and enhancing human-machine interactions in virtual reality and teleoperator systems.

International Consortium for Medical Imaging Technology
Development and implementation of information technology that will lead to improved medical diagnosis and health care as well as reductions in costs.

Laboratory for Biomechanics of Cells and Biomolecules
Development of new instruments for the measurement of mechanical properties on the scale of a single cell or single molecule to better understand the interactions between biology and mechanics.

Newman Laboratory for Biomechanics and Human Rehabilitation
Research on bioinstrumentation, neuromuscular control, and technology for diagnosis and remediation of disabilities.
Nano/Micro Science and Technology

Pappalardo Laboratory for Micro/Nano Engineering
Creation of new engineering knowledge and products on the nano and micro scale through multidomain, multidisciplinary, and multiscale research.

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William Plummer, PhD
John Psarouthakis, PhD
Mark Schattenburg, PhD
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COURSE  2  

MECHANICAL  ENGINEERING

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Hayden Marcillo, PhD  
In K. Mun, PhD  
Takatoshi Nakamura, PhD  
Kailas Narendran, MS  
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Pyush Patel  
Christophe Prud’homme, PhD  
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Professor of Mechanical Engineering, Emeritus  
David Gordon Wilson, PhD  
Professor of Mechanical Engineering, Emeritus
The Department of Nuclear Science and Engineering provides undergraduate and graduate education for students interested in developing the peaceful applications of nuclear science and engineering for societal needs. This is an exciting time to study Nuclear Science and Engineering: society’s interest in, and need for, a clean energy source such as nuclear energy is at a 20-year high. The applications of other nuclear technologies in medicine and industry have focused attention on the value of a strong nuclear science and engineering program. In response to this demand, the department has developed a discipline-focused program of study that prepares students for the many diverse applications of nuclear science and technology. Applied nuclear science is the core discipline, underlying all these applications, that includes low energy nuclear physics, the interaction of ionizing radiation with matter, and plasma science and technology.

The department’s view of nuclear science and engineering is manifest in our unified core curriculum for all our graduate students and our discipline-based undergraduate program. Once the core material is mastered, students can select from a wide variety of applications through more specialized subjects.

Most of the applications fall within three main subcategories: nuclear power, plasma physics and fusion technology, and the broad area of nuclear science and technology. In keeping with MIT’s longstanding contributions to the well-being of the nation, the department aims to educate the individuals who will make the key scientific and engineering advances in these societal important fields. Each of the three basic research areas involves substantial faculty and student activities and is apportioned as follows: nuclear power, 37 percent; nuclear science and technology, 35 percent; and plasma physics and fusion technology, 28 percent. A synopsis of these activities follows.

Nuclear Power. Nuclear reactors, powered by the fissioning of heavy elements such as uranium, have many applications. These include the generation of electricity, process heat and hydrogen, the propulsion of submarines and ships, the generation of on-board space-craft power for deep space exploration, the transmutation of long-lived radioactive elements, and the production of radioisotopes for medical and other biological and industrial applications.

The generation of electricity by nuclear power is probably the most familiar application. In some countries, the fraction of electricity obtained from nuclear power is greater than 80 percent. In the United States, it is about 20 percent. Concerns about the unreliability of fossil fuel supplies and the fact that demand is catching up and overtaking existing domestic supplies of electricity have led to a resurgence of interest in the design of advanced nuclear reactors. This interest is further enhanced by the fact that nuclear reactors, both existing and advanced designs, emit no greenhouse gases. Virtually all-national and international energy planners are in agreement that the United States and the rest of the world will not be able to meet their future energy needs without a substantially increased contribution from nuclear power.

The safe and economical development, design, construction, and operation of nuclear power plants and their related fuel re-cycling facilities is a major field of engineering. Future Nuclear Science and Engineering research goals are focused on: developing new advanced nuclear reactor designs that include passive safety features; developing innovative new proliferation-resistant fuel cycles; extending the life of nuclear fuels and structures; and reducing the capital and operating costs of nuclear power stations. The goal is to make nuclear power the most economical, safe, and environmentally friendly way of generating electricity, thereby making a major contribution to our energy independence and a sustainable global climate.

The Department of Nuclear Science and Engineering is also an active participant in MIT’s interdisciplinary programs of instruction and research in the management of complex technological systems and technology and public policy. This is a growing and important area, since policy makers need more effective tools in assessing complex systems and human behavior.

Plasma Physics and Fusion Technology. A different source of nuclear energy results from the controlled fusion of light elements, hydrogen and its isotopes in particular. Since the basic source of fuel for fusion can be easily and inexpensively extracted from the ocean, the supply is virtually inexhaustible. Fusion reactions can only readily occur in a fully ionized plasma heated to super high temperatures (150 million K). Such hot plasmas cannot be contained by material walls and are usually confined instead by strong magnetic fields. Recent progress within the international fusion community increases the likelihood that controlled fusion will become a practical source of energy within the next half-century. Attainment of a fusion power plant involves the solution of many intellectually challenging physics and engineering problems. Included among these challenges are: a mastery of the sophisticated field of plasma physics; the discovery of improved magnetic geometries to enhance plasma confinement; the development of materials capable of withstanding high stresses and exposure to intense radiation; and the need for great engineering ingenuity in integrating fusion power components into a practical, safe, and economical system. The department has strong programs in plasma fundamentals, materials for intense radiation fields, and engineering of fusion systems.

The fundamentals of plasmas also underlie novel methods for treatment of toxic gases, magnetohydrodynamic energy conversion, and ion propulsion, all topics of interest in the department. Students concentrating on applied plasma physics are trained not only to contribute to the advancement of controlled fusion but also to apply their knowledge in current industrial applications. In these plasma programs, the Department of Nuclear Science and Engineering is an active participant in MIT’s broad, interdisciplinary program of research and instruction in plasma physics and its varied applications.

Nuclear Science and Technology. The department’s nuclear science and technology program is concerned with a wide range of nuclear science and engineering applications involving medicine and biology, information processing, materials research, industrial processes, and nuclear waste remediation.

Bionuclear science and engineering utilizes nuclear processes in a variety of ways that impact medicine and biology. For example, nuclear radiation can be used as a medical diagnostic tool through a variety of imaging techniques. It can also be used for therapy: the boron-neutron interaction is being used to treat various forms of brain cancer. Research is underway to apply this treatment to other types of cancer and to rheu-
matoid arthritis. A microbeam accelerator has just been constructed, whose goal it is to allow for the first time a first-principles understanding of the interaction of radiation with biological materials at the subcellular level.

Nuclear science and engineering (such as fission and fusion) has traditionally dealt with random processes, for which only the statistics can be controlled. A new frontier in nuclear science and engineering is to precisely control the quantum mechanical wave function of atomic and subatomic systems. Thus far, this has been achieved only in low energy processes, particularly nuclear magnetic resonance, a form of nuclear spectroscopy which has allowed the basic techniques needed for quantum control to be explored in unprecedented detail. The department has initiated an ambitious program in this area, which promises to be widely applicable in nanotechnology. The ultimate achievement would be the construction of a “quantum computer,” which would be capable of solving problems that are far beyond the capacities of classical computers. Other significant applications are secure communication and the direct simulation of quantum physics.

A cross-cutting area of research in the department involves the area of nuclear materials research. Understanding how radiation interacts with biological materials is a major interest in the nuclear science and technology program. However, materials also are critical in the nuclear power and fusion programs. Here, in order to achieve the full potential of nuclear energy from either fission or fusion reactors, it is necessary to develop special materials capable of withstanding intense radiation for long periods of time. It is also crucial to understand the phenomenon of corrosion in a radiation environment.

Nuclear science and engineering makes important contributions to a wide range of industrial applications. For example, nuclear techniques are being used and developed for the rapid, non-intrusive inspection of aircraft baggage and cargo. Another application is the development of a “plasma-window” that separates a vacuum region from a high-pressure region without the need for a solid material structure. Such a window then allows ultrahigh-power accelerator particle beams to propagate from one region to the other without concern for window damage, which is often a limiting factor. Nuclear techniques have been used to develop a non-invasive solidification sensor for the metal casting industry, a sensor of great practical, quality control, and economic importance. Nuclear technologies have been used to eliminate *E. coli* bacteria from food and anthrax from our mail system.

Undergraduate and graduate students in other departments at MIT who wish to learn how their major professional fields may be utilized in nuclear science and technology applications may find certain offerings by the Department of Nuclear Science and Engineering of interest, such as the medically oriented bionuclear science and engineering program, nuclear power plant engineering, applied plasma physics, nuclear materials engineering, and the interdepartmental program on risk-benefit analysis of technology.

**UNDERGRADUATE STUDY**

**Bachelor of Science in Nuclear Science and Engineering/Course 22**

The Department of Nuclear Science and Engineering’s undergraduate program provides a broad foundation in nuclear science and engineering in preparation for careers in the nuclear power industry or the applied radiation industry, such as medical technology, or for graduate study in nuclear science and engineering and related disciplines. The field of study is very broad and flexible, offering students many options for future study based on a solid foundation. The program develops engineering fundamentals in radiation production, interactions and measurement, and in the design of nuclear systems. In addition, the program introduces students to thermal-fluid engineering, electronics and computer methods. The program is designed to be analytical and grounded in an understanding of low-energy nuclear physics. The curriculum allows for opportunity to expand into many diverse areas.

The department offers one undergraduate program leading to a Bachelor of Science in Nuclear Science and Engineering, Course 22, which is normally completed in four years. A characteristic of the curriculum is to develop practical skills through hands-on education. This is accomplished through a laboratory course on radiation physics, measurement, and protection (22.09), and through the laboratory components and exercises in electronics (22.071), imaging (22.058), and computational courses. The concept of hands-on learning is continued with a 12-unit design course focusing on nuclear systems and a 12-unit undergraduate thesis that is normally organized between the student and a faculty member of the department. Thesis subjects can touch on any area of nuclear science and engineering, including nuclear energy applications (fission and fusion) and nuclear science and technology (medical, physical, chemical and material applications).

Additional information may be obtained from the student’s departmental advisor or from the department’s Academic Office (Room 24-102).

The Bachelor of Science in Nuclear Science and Engineering prepares students for careers in the design, analysis and operation of fission reactors, in various applications of radiation (including biomedical), and for graduate study in a wide range of engineering and physical sciences.

The Course 22 degree program is accredited by the Accreditation Board for Engineering and Technology.

Subject requirements and options are described in the preceding paragraphs and chart. A bachelor’s degree thesis of 12 units is required.

**Minor Program in Nuclear Science and Engineering**

The requirements of a Minor in Nuclear Science and Engineering are as follows:

*Students must complete a total of six subjects, including 8.03 and 18.03 as prerequisites to departmental subjects. The subjects should constitute a coherent program built on the core courses:*

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.01</td>
<td>Introduction to Ionizing Radiation</td>
</tr>
<tr>
<td>22.02</td>
<td>Introduction to Applied Nuclear Physics</td>
</tr>
<tr>
<td>22.05</td>
<td>Neutron Science and Reactor Physics</td>
</tr>
<tr>
<td>22.06</td>
<td>Engineering of Nuclear Systems</td>
</tr>
<tr>
<td>22.058</td>
<td>Principles of Tomographic Imaging</td>
</tr>
<tr>
<td>22.09</td>
<td>Principles of Nuclear Radiation Measurement and Protection</td>
</tr>
</tbody>
</table>
The department’s minor advisor will ensure that each minor program forms a coherent group of subjects.

Combined Bachelor’s and Master’s Programs
The five-year programs leading to a joint Bachelor of Science in Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, Nuclear Science and Engineering, or Physics and a Master of Science in Nuclear Science and Engineering are helpful to students who, early in their undergraduate studies, decide to pursue a graduate degree in nuclear science and engineering. Students desiring to enter such a program must meet the graduate admission requirements of the Department of Nuclear Science and Engineering and submit their applications for admission at the end of their junior year. If admitted, the student arranges a program with the registration officers of the two participating departments.

The nuclear science and engineering thesis requirements of the two degrees may be satisfied either by completing both an SB thesis and an SM thesis, or by completing an SM thesis and any 12 units of graduate credit.

For further information, interested students should contact either their undergraduate department or the Department of Nuclear Science and Engineering.

Inquiries
Further information on undergraduate programs, admissions, and financial aid may be obtained from the department’s Academic Office, Room 24-102, MIT, 617-258-5682.

Graduate Study
The nuclear science and engineering profession is broad and many undergraduate disciplines provide suitable preparations for graduate study. While the graduate program splits into three areas after the initial core set of courses, many incoming students change their area of interest after joining the program. The Department of Nuclear Science and Engineering is dedicated to attracting a diverse class of well-prepared engineers and scientists.

### Bachelor of Science in Nuclear Science and Engineering/Course 22

<table>
<thead>
<tr>
<th><strong>General Institute Requirements (GIRs)</strong></th>
<th><strong>Subjects</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
</tr>
<tr>
<td>[can be satisfied from among 8.03, 18.03 or 18.034, 22.071, 22.01 and 22.02 in the Departmental Program]</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement [can be satisfied by 22.09 in the Departmental Program]</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td>17</td>
</tr>
</tbody>
</table>

**Communication Requirement**
The program includes a Communication Requirement of 4 subjects:
- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the major (CI-M).

**PLUS Departmental Program**

<table>
<thead>
<tr>
<th><strong>Subjects</strong></th>
<th><strong>Units</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Requirements</td>
<td>84</td>
</tr>
<tr>
<td>2.005 Thermal-Fluids Engineering I, 12, REST; 8.02, 18.03</td>
<td></td>
</tr>
<tr>
<td>2.071 Introduction to Electronics, 12, REST; 18.01</td>
<td></td>
</tr>
<tr>
<td>8.03 Physics III, 12, REST; 8.02*, 18.02</td>
<td></td>
</tr>
<tr>
<td>12.010 Computational Methods of Scientific Programming, 12; 18.01, 18.02, 8.01</td>
<td></td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; 18.02, 18.014</td>
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</tr>
<tr>
<td>or 18.034 Differential Equations, 12, REST; 18.02, 18.014</td>
<td></td>
</tr>
<tr>
<td>18.085 Mathematical Methods for Engineers I, 12, 18.03</td>
<td></td>
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<tr>
<td>22.01 Introduction to Ionizing Radiation, 12, REST</td>
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<tr>
<td>Required Nuclear Science and Engineering Core Subjects</td>
<td>72</td>
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<tr>
<td>22.02 Introduction to Applied Nuclear Physics, 12, REST; 8.02, 18.02, 22.01</td>
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<tr>
<td>22.033 Nuclear Systems Design Project, 12; 22.06</td>
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<tr>
<td>22.05 Neutron Science and Reactor Physics, 12; 18.03, 22.02</td>
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<tr>
<td>22.058 Principles of Tomographic Imaging, 12; 8.02, 18.03</td>
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<tr>
<td>22.06 Engineering of Nuclear Systems, 12; 2.005, 22.02, 22.05</td>
<td></td>
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<tr>
<td>22.09 Principles of Nuclear Radiation Measurement and Protection, 12, LAB, CI-M; 22.02</td>
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</tr>
<tr>
<td>Required Undergraduate Nuclear Science and Engineering Thesis</td>
<td>12</td>
</tr>
<tr>
<td>22.0Th Undergraduate Thesis Tutorial (minimum of 3 units), 22.09</td>
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</tr>
<tr>
<td>22.0Th Thesis (minimum of 9 units), CI-M; 22.0Th</td>
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<tr>
<td>Restricted Electives</td>
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<td>Choose one of the following:</td>
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<tr>
<td>2.006 Thermal-Fluids Engineering II, 12; 2.005, 18.03</td>
<td></td>
</tr>
<tr>
<td>2.791 Quantitative Physiology: Cells and Tissues, 12; 2.003, 8.02, 18.03</td>
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</tr>
<tr>
<td>5.12 Organic Chemistry I, 12; 5.11 or 5.111 or 5.112 or 3.091</td>
<td></td>
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<tr>
<td>8.04 Quantum Physics I, 12; 8.03*, 18.03</td>
<td></td>
</tr>
<tr>
<td>8.07 Electromagnetism II, 12; 8.05, 18.03</td>
<td></td>
</tr>
<tr>
<td>22.00 Introduction to Modeling and Simulation, 12, REST; 18.03 or 3.016</td>
<td></td>
</tr>
<tr>
<td>Departmental Program Units That also Satisfy the GIRs</td>
<td>(96)</td>
</tr>
<tr>
<td>Unrestricted Electives</td>
<td>48</td>
</tr>
<tr>
<td><strong>Total Units Beyond the GIRs Required for SB Degree</strong></td>
<td>192</td>
</tr>
</tbody>
</table>

No subject can be counted both as part of the 17-subject GIRs and as part of the 192 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

Notes
*Alternate prerequisites are listed in the subject description.
For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
An undergraduate degree in physics, engineering physics, chemistry, mathematics, metallurgy, or chemical, civil, electrical, mechanical, or nuclear science and engineering can provide a foundation for graduate study in nuclear science and engineering. Optimum undergraduate preparation would include the following:

Physics—at least three introductory courses covering classical mechanics, electricity and magnetism, and wave phenomena. An introduction to quantum mechanics is quite helpful, and an advanced course in electricity and magnetism (including a description of time-dependent fields via Maxwell’s equations) is recommended for those wishing to specialize in fusion.

Mathematics—it is essential that incoming students have a solid understanding of mathematics, including the study and application of ordinary differential equations. It is highly recommended that students also have studied partial differential equations and linear algebra.

Chemistry—at least one term of general, inorganic, and physical chemistry.

Engineering fundamentals—the graduate curriculum builds on a variety of engineering skills, and incoming students are expected to have had an introduction to thermodynamics, fluid mechanics, heat transfer, electronics and measurement, and computation and numerical methods. A subject covering the mechanics of materials is recommended, particularly for students wishing to specialize in fission.

Laboratory experience is essential. This may have been achieved through an organized course, and ideally was supplemented with an independent undergraduate research activity or a design project.

Applicants for admissions are required to take the Graduate Record Examination (GRE).

Master of Science in Nuclear Science and Engineering
The object of the Master of Science program is to give the student a good general knowledge of nuclear science and engineering and to provide a foundation either for productive work in the nuclear field or for more advanced graduate study. The general requirements for the SM degree are listed under Graduate Education in Part 1. Subject 22.101 Applied Nuclear Physics or its equivalent is required for all Master of Science degree candidates.

Other subjects may be selected in accordance with the student’s particular field of interest. Most Master of Science candidates specialize in one of three alternative fields: fission nuclear technology, applied plasma physics, or nuclear science and technology. Detailed descriptions of the subjects available in each of these areas may be found in the Course 22 listings in Part 3.

Students with adequate undergraduate preparation normally need 18 months to two years to complete the requirements for the Master of Science. Additional information concerning the requirements for the Master of Science in Nuclear Science and Engineering, including lists of recommended subjects, may be obtained from the department’s Academic Office (Room 24-102).

Master of Science in Technology and Policy
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 TPP 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 in the Engineering Systems Division section Part 2, or visit http://tppserver.mit.edu/.

Nuclear Engineer
The program of study leading to the Nuclear Engineer’s degree provides deeper knowledge of nuclear science and engineering than is possible in the master’s program and is intended to train students for creative professional careers in engineering application or design.

The general requirements for this degree, as described under Graduate Education in Part 1, include 162 units of subject credit plus a thesis. Each student must plan an individually selected program of study, approved in advance by the faculty advisor, and must complete, and orally defend, a substantial project of significant value.

The objectives of the program are to provide the candidate with a broad knowledge of the profession and to develop competence in engineering applications or design. The emphasis in the program is more applied and less research-oriented than the doctoral program.

The engineering project required of all candidates for the Nuclear Engineer’s degree is generally the subject of an engineer’s thesis. A student with full undergraduate preparation normally needs two years to complete the program. A student who satisfies the requirements for the engineer’s degree is simultaneously approved for the SM by the Department of Nuclear Science and Engineering. Additional information may be obtained from the department.

Doctor of Philosophy and Doctor of Science
The program of study leading to either the Doctor of Philosophy or the Doctor of Science degree aims to give a comprehensive knowledge of nuclear science and engineering, to develop competence in advanced engineering research, and to develop a sense of perspective in assessing the role of nuclear science and technology in our society.

General requirements for the doctorate are described under Graduate Education in Part 1 and in the Graduate School Policy and Procedures Manual. The specific requirements of the Department of Nuclear Science and Engineering are the math and physics competency requirement, the engineering requirement, the general examination, the core/major/minor program requirement, and the doctoral thesis.

Upon satisfactory completion of the requirements, the student ordinarily receives a PhD unless he or she requests an ScD. The requirements for both degrees are the same.

Students admitted for the Master of Science or Nuclear Engineer’s degree must apply to the Department of Nuclear Science and Engineering’s Admissions Committee for admission to the doctoral program.

Students admitted for a doctoral degree must complete the math and physics competency requirement and the engineering requirement prior to taking the general examination. Before starting doctoral research, each student
is required to pass a general examination whose purpose is to establish intellectual potential as well as breadth and depth of knowledge. The general exam has two sections: a written component and an oral component. Both components must be passed in order to register for doctoral thesis credit.

Candidates for a doctoral degree must also satisfactorily complete (with an average grade of B or better) an approved program of advanced studies—the core/major/minor requirement. The program requires that students take not less than 84 credit hours of subjects (excluding special problems), of which two subjects (24 units) must be selected from the following courses (the core): 22.101, 22.105, and 22.106. Three subjects (36 units) comprise a field of specialization (the major) that will be closely related to the student’s doctoral thesis topic. Two subjects (24 units) must be coordinated subjects clearly outside the field of specialization (the minor). None of the 36 units selected by the student in the field of specialization (the major) may be from the list of subjects specified for general examination questions chosen by the student.

Also available is a joint degree program offered by the Department of Nuclear Science and Engineering’s Radiological Sciences Graduate Program and the Harvard-MIT Division of Health Sciences and Technology. Decisions regarding admission and award of the doctoral degree are made jointly. In addition to a strong background in the physical and engineering sciences, applicants should complete two undergraduate subjects in biology or biochemistry before entrance, and must complete three additional life sciences subjects prior to receiving the doctoral degree as part of the coursework toward fulfilling the NSE core/major/minor program. To supplement the program’s academic training, a one-month clinical practicum in one of the affiliated Boston-area hospitals is also required. Students submit and defend a doctoral thesis before a committee of MIT faculty, including members from NSE and HST, in accordance with the interdisciplinary nature of the program.

Doctoral research may be undertaken either in the Department of Nuclear Science and Engineering or in a nuclear-related field in another department. Appropriate areas of research are described generally in the introduction to the department, and a detailed list may be obtained from the Department of Nuclear Science and Engineering.

Research Facilities
The department’s programs are supported by a number of outstanding experimental facilities for advanced research in nuclear science and engineering.

The MIT Research Reactor in the Nuclear Reactor Laboratory operates at a power of 5 MW and is fueled with U-235 in a compact light-water cooled core surrounded by a heavy-water reflector. This reactor provides a wide range of radiation-related research and teaching opportunities for the students and faculty of the department. Major programs to study corrosion in a nuclear environment are currently in place. The clinical trials of boron neutron capture therapy are being conducted in the newly renovated epithelial neutron beam. Details of the laboratory’s research programs and facilities are given in the section on Interdisciplinary Research and Study. The department utilizes extensive experimental plasma facilities for the production and confinement of large volumes of highly ionized plasmas and for studies of plasma turbulence, particle motions, and other phenomena.

Most of the departmental research on plasmas and controlled fusion is carried out in the Plasma Science and Fusion Center. The department has played a major role in the design and development of high magnetic-field fusion devices. Currently there are three major plasma experiments at MIT—the Alcator C-Mod Tokamak, the Levitated Dipole Experiment, and the Versatile Toroidal Facility (VTF)—all located in the Plasma Science and Fusion Center (described in the section on Interdisciplinary Research and Study in Part 1). Through its activities in the Plasma Science and Fusion Center, the department is also the national leader in the design of magnets, both copper and superconducting.

Within the Spatial Nuclear Magnetic Resonance Laboratory, the full gamut of spatial nuclear magnetic resonance (NMR) techniques can be undertaken in one setting. Topics explored in the laboratory include NMR microscopy; studies of porous, granular, and soft matter; quantum chaos; coherent multi-body dynamics; and experimental implementation of quantum computers.

A unique, high-current tandem accelerator, developed for use in medical research, is available in the Accelerator Beam Applications Laboratory, and is capable of providing intense, low-energy neutrons for basic research into boron neutron capture therapy and other uses of the 10B(n,a) nuclear reaction. A second proton beam can be used as a microprobe for spatially resolved elemental analysis.

In the Whitaker College Biomedical Imaging and Computational Laboratory, a variety of radiation therapy and medical physics research projects are in progress. The laboratory houses computer workstations, which are used primarily for Monte Carlo simulation of different radiation types and for image processing analysis.

In addition to the above facilities, the department has a nuclear instrumentation laboratory and a 14 MeV neutron source. Laboratory space and shop facilities are available for research in all areas of Nuclear Science and Engineering. A state-of-the-art scanning electron microscope that can be used to study irradiated specimens is available. A number of computer workstations dedicated to simulation, modeling, and visualization, as well as MIT’s extensive computer facilities, are used in research and graduate instruction.

Financial Aid
Financial aid for graduate students is available in the form of research and teaching assistantships, department-administered fellowships, and supplemental subsidies from the College Work-Study Program. Assistantships are awarded to students with high quality academic records. The duty of a teaching assistant is to assist a faculty member in the preparation of subject materials and the conduct of classes, while that of a research assistant is to work on a research project under the supervision of one or more faculty members.

Most fellowships are awarded in April for the following academic year. Assistantships are awarded on a semester basis. The assignment of teaching assistants is made before the start of each semester, while research assistants can be assigned at any time. Essentially all students admitted to the graduate program receive financial aid for the duration of their education.
Application for financial aid should be made to Professor Sidney Yip, Room 24-102, MIT, 617-253-3809.

Inquiries
Additional information on graduate admissions and academic and research programs may be obtained from the department’s Academic Office, Room 24-102, MIT, 617-253-3814, email cegan@mit.edu.

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Head of Department

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Professor of Nuclear Science and Engineering and Engineering Systems
Ronald George Ballinger, ScD
Professor of Nuclear Science and Engineering and Materials Science and Engineering
Sow-Hsin Chen, PhD
Professor of Nuclear Science and Engineering
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Professor of Nuclear Science and Engineering
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Professor of the Practice, Nuclear Science and Engineering
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TEPCO Professor of Nuclear Engineering
Professor of Mechanical Engineering
Director, Center for Advanced Nuclear Energy Systems
Richard Keith Lester, PhD
Professor of Nuclear Science and Engineering
Director, Industrial Performance Center
Ronald Richard Parker, PhD
Professor of Electrical Engineering and Nuclear Science and Engineering
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Sidney Yip, PhD
Professor of Nuclear Science and Engineering and Materials Science and Engineering

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Kim Molvig, PhD
Associate Professor of Nuclear Science and Engineering

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Assistant Professor of Nuclear Science and Engineering
Alan Pradip Jasanoff, PhD
Assistant Professor of Nuclear Science and Engineering

Senior Lecturer
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Head, Plasma Technology and Systems, Plasma Science and Fusion Center
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Principal Research Scientist
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Principal Research Engineer, Nuclear Reactor Laboratory

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Chandrasekhar Ramanathan, ScD

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Peter Stahle, BSME

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Benjamin Levi, PhD
Jeongyoun Lim, PhD
Xi Lin, PhD

Research Affiliates
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Matteo Broccio, PhD
Gongyin Chen, PhD
Douglas Coates
John McGregor Dobbs, PhD
Andrew Hodgdon, MSc
Julie Kastner, BSc
Walter Kato, PhD
Genrich Krasko, PhD
Ning Li, PhD
Werner Maas, PhD
Ross Mair, PhD
Francesco Mallamace, PhD
William McBrine, MS
Eric McFarland, PhD
Thomas McKrell, PhD
Shigenobu Ogata, PhD
David Perticone, PhD
Mark Rivard, PhD
Pradip Saha, PhD
Jeffrey Schweitzer, PhD
Pabitra Sen, PhD
Grum Teklemariam, PhD
John Watterson, PhD
Zhiwen Xu, PhD
Bilge Yildiz, PhD

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Institute Professor, Emeritus

Gordon Lee Brownell, PhD
Professor of Nuclear Science and Engineering, Emeritus

Michael John Driscoll, ScD
Professor of Nuclear Science and Engineering, Emeritus

Thomas Henderson Dupree, PhD
Professor of Nuclear Science and Engineering and Physics, Emeritus

Elias Panayiotis Gyftopoulos, ScD
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David Dayton Lanning, PhD
Professor of Nuclear Science and Engineering, Emeritus

Ronald Michael Latanision, PhD
Professor of Materials Science and Nuclear Science and Engineering, Emeritus

John Edward Meyer, PhD
Professor of Nuclear Science and Engineering, Emeritus

Kenneth Calvin Russell, PhD
Professor of Metallurgy and Nuclear Science and Engineering, Emeritus

Neil Emmanuel Todreas, ScD
KEPCO Professor of Nuclear Science and Engineering, Emeritus
Professor of and Mechanical Engineering, Emeritus
Effective January 1, 2005, the Department of Ocean Engineering (Course 13) merged with the Department of Mechanical Engineering (Course 2).

For information on ocean engineering programs, degrees, subjects, faculty, and staff, please refer to the Department of Mechanical Engineering listings in Part 2 of this Bulletin.
The School of Humanities, Arts, and Social Sciences offers students the chance to explore creative expressions of the human imagination, understand the human past, and examine social, economic, and political change over time and the cultural and institutional contexts in which science and technology are rooted.
The great strength of MIT lies not only in the fact that it fosters creativity and innovation in science and technology, but that it also pioneers in exploring the social and cultural environments in which science and technology are produced.

A chief concern of the School’s undergraduate program has long been the provision of subjects to fulfill the Institute’s Humanities, Arts, and Social Sciences Requirement. The object of the requirement, broadly stated, is to ensure that every undergraduate at MIT is exposed to a wide range of interpretive and analytic approaches in the humanities, arts, and social sciences.

Humanities, arts, and social science programs emphasize teaching, research, and performance. Through their publications, lectures, and seminars, the faculty strive to expand the frontiers of human knowledge and awareness. Interdisciplinary collaboration is a hallmark of this activity.

The School’s five doctoral programs (Economics, History, Anthropology, and Science, Technology and Society [HASTS], Linguistics, Philosophy, and Political Science) are among the leading graduate programs of their kind in the world. They prepare students primarily for teaching and research careers in universities and colleges, but also for government service, industry, and finance. The School also offers master’s degrees in Comparative Media Studies, Political Science, and Science Writing.

New Directions

Minor programs have been established in all of the School’s sections, programs, and departments, as well as in African and African Diaspora Studies, Applied International Studies, Chinese, Comparative Media Studies, East Asian Studies, European Studies, Latin American Studies, Middle Eastern Studies, Psychology, Russian Studies, and Women’s Studies. These minors offer another opportunity for focused undergraduate exploration in the humanities, arts, and social sciences. For further details, see the section on HASS Minors in Regional Studies.

In response to the increasing demand on US campuses for internationalization of the curriculum, the Foreign Languages and Literatures Section has created language and culture programs in Japanese and Chinese. The Japanese Language and Cultural Program has built the most technologically advanced Japanese language and culture education curriculum in the world, using online computer networks and interactive videos. The MIT International Science and Technology Initiatives, located at the Center for International Studies, support student internships in Japan, China, India, France, Italy, Germany, and Mexico.

The School’s newest graduate degree program is an SM in Science Writing, which focuses on the ability to interpret and explain science to the wider public. The School also offers an SM degree and an SB degree in Comparative Media Studies; both degree programs focus on new and old media and their global impact on society, economy, and politics.

History

MIT’s Course 21 (Humanities) was considered innovative when it was established in the 1950s, although its roots go back to the opening of the Institute in 1865. The 1865 course bulletin offered a curriculum option called the Course of Science and Literature, which encompassed the study of humanities and social science subjects. The science and literature option developed into Course 9, and by 1882 was renamed General Studies, offering “a larger amount of history, economics, language, and literature than is possible in technical courses.”

After the Second World War, MIT’s evaluation of general and humanistic education changed dramatically. The Institute saw the need to emphasize the “humanistic-social stem” of the engineering curriculum. During the postwar period, the School of Humanities and Social Studies (later the School of Humanities and Social Science) was established, allowing students to pursue a degree that combined engineering or science with humanities in a 60/40 ratio over four years. By this time, the Department of Economics and Social Science had been established within the School, attracting some of the nation’s best graduate students and achieving recognition as a leading department.

During the 1960s the School grew rapidly, was reorganized into most of its current departments and sections, and began to grant full-scale degrees. In 1965, Political Science became a separate department, offering both undergraduate and graduate degrees. Philosophy, History, Literature, and Music all emerged as separate sections. In 1966, for the first time ever, MIT students could major in the humanities.

In the 1970s the School continued to define separate programs: the Anthropology and Archaeology Program (now Anthropology Program), established in 1971, and the Writing Program (now Program in Writing and Humanistic Studies), established in 1974. A rearrangement of sections in 1976 produced the Foreign Languages and Literatures Section and the Department of Linguistics and Philosophy. The interdisciplinary Program in Science, Technology, and Society began in 1977, and in 1988 a doctoral program in the History and Social Study of Science and Technology (later called the History, Anthropology, and Science, Technology and Society program) was established in collaboration with the faculties of History and Anthropology. In 1990, the School replaced the generic SB degree in Humanities with SB degrees in specified areas of humanistic study: Anthropology, History, Literature, Foreign Languages and Literatures, Music, and Writing. In 1999, it introduced an SM degree in Comparative Media Studies and in 2002, an SM degree in Science Writing. In 2003, an SB degree in Comparative Media Studies was introduced. To reflect the growth and incorporation of the arts at MIT and in celebration of its 50th anniversary in 2000, the School changed its name to the School of Humanities, Arts, and Social Sciences.

Interdepartmental Programs

The interdepartmental centers, groups, and programs that reside in the School of Humanities, Arts, and Social Sciences include the following:

Center for International Studies
Women’s Studies Program
Knight Science Journalism Fellows Program

See Interdisciplinary Research and Study in Part 1 for further information.
## Degrees Offered in the School of Humanities, Arts, and Social Sciences

<table>
<thead>
<tr>
<th>Course</th>
<th>SB</th>
<th>SM</th>
<th>PhD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropology</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Comparative Media Studies</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Economics</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Foreign Languages and Literatures</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>History</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Humanities</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Linguistics and Philosophy</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Literature</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Music and Theater Arts</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Political Science</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Program in Science, Technology, and Society</td>
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<td>-</td>
</tr>
<tr>
<td>Writing and Humanistic Studies</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>

*This undergraduate degree program was authorized by the Committee on the Undergraduate Program to accept students, beginning in 2003, and will be reviewed in fall 2008. In the event that the degree program is not approved for permanent status by the Faculty in academic year 2008–2009, accommodations will be made for any student enrolled in the major prior to Fall 2008 to complete the degree program. Students may contact the director of Comparative Media Studies, Henry Jenkins, for more information.*

**Students majoring in German or doing a "major departure" (an independently designed major in one of several specified fields) receive the generic SB degree in Humanities.**

*Note: Many departments make it possible for a graduate student to pursue a simultaneous master’s degree.*

## Publications

The Dean’s Office publishes the brochure *School of Humanities, Arts, and Social Sciences* at MIT and the newsletter of the School of Humanities, Arts, and Social Sciences, *Soundings*. For copies of these publications, contact the Office of the Dean, School of Humanities, Arts, and Social Sciences, Room E51-255, MIT.

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Interim Dean

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Anne Marie Michel, MA  
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Susan Mannett, BA  
Director, Human Resources for SHASS

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Director, Humanities, Arts, and Social Sciences Education Office

### Professors Emeriti

Martin Dyck, PhD  
Professor of German and Literature, Emeritus

William Nash Locke, PhD  
Professor of Modern Languages, Emeritus  
Director of Libraries, Emeritus

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**Note:**

- Many departments make it possible for a graduate student to pursue a simultaneous master’s degree.
Anthropology studies humankind from a comparative perspective that emphasizes the diversity of human behavior and the importance of culture in explaining that diversity. While the discipline encompasses the biological nature of our species and the material aspects of human adaptation, it takes as fundamental the idea that we respond to nature and natural forces in large part through culture. Anthropology, then, is the study of human beings as cultural animals. Sociocultural anthropology draws its data from the direct study of contemporary peoples living in a wide variety of circumstances, from peasant villagers and tropical forest hunters and gatherers to urban populations in modern societies, as well as from the history and prehistory of those peoples.

The Anthropology Program at MIT offers students a broad exposure to the discipline as well as an anthropological perspective on problems and issues relevant to other fields in the humanities, social sciences, science, and engineering. It also provides more intensive introduction to areas of faculty specialization, which include social and political organization; environmentalism; religion and symbolism; photography and film; law; gender studies; nationalism; and the anthropology of medicine and scientific research. Geographical specializations include cultures of Africa, Latin America, the Middle East, and the United States.

The anthropology curriculum is divided into six groups that show the breadth of the field, with particular emphases. Introductory subjects and subjects intended for majors and minors range from 100 to 199. Social anthropology subjects that focus on specific topics are assigned to the 200 to 299 set. The subjects dealing with technology in cultural context, ranging from 300 to 399, focus on how technologies derive from and relate to their cultural settings. The next group, areal and historical studies, ranging from 400 to 599, includes subjects devoted to different regions and culture areas of the world. The offerings ranging from 600 to 699 constitute advanced graduate subjects.

Students taking a concentration in anthropology take 21A.100 Introduction to Anthropology, and two other subjects. Anthropology subjects qualify for several interdisciplinary concentrations, including those in Women’s Studies, Latin American Studies, and Technology, Culture, and Development.

Bachelor of Science in Anthropology/ Course 21A
The undergraduate program leading to the degree of Bachelor of Science in Anthropology (Course 21A) provides a thorough grounding in cultural anthropology.

Majors learn about the concept of culture, the nature of anthropological fieldwork, and the connections between anthropology and the other social sciences. They study the various theories that attempt to explain human behavior as well as the range of methods anthropologists use to analyze data. Students can focus on geographical areas, such as Latin America or modern western society, and on issues like neocolonialism, ethnic conflict, human rights, expressive culture, or globalization.

The anthropology student comes to understand that the hallmark of the discipline is the comparative study of human societies. Emphasis is on understanding diversity and the importance of the concept of culture in explaining that diversity, as well as on learning about the universals of behavior that underlie diversity.

Minor Program in Anthropology
The Minor Program in Anthropology consists of six subjects arranged into three tiers as shown below. Students create individual programs with the help of the minor advisor to ensure that they gain a coherent introduction to the methods, approaches, and some of the results of the discipline.

Tier I  One subject:
21A.100 Introduction to Anthropology

Tier II  Four subjects with a unifying theme

Tier III  One subject:
21A.110 Seminar in Anthropological Theory
21A.112 Seminar in Ethnography and Fieldwork

Joint Degree Programs
Joint degree programs are offered in anthropology in combination with a field in engineering or science (21E, 21S). See the joint major programs listed under Humanities.

Subject 21A.100 is strongly recommended as a preliminary subject for all anthropology degree programs.

In collaboration, the Anthropology Program, the History faculty, and the Program in Science, Technology, and Society offer a Program in History, Anthropology, and Science, Technology and Society (HASTS) leading to the PhD; see the description under the Program in Science, Technology, and Society.

Subjects in anthropology are numbered 21A.100 through 21A.999 in Part 3. Further information on subjects and programs may be obtained from the Anthropology Program Office, Room 16-267, 617-452-2837.

Faculty and Staff
Faculty and Teaching Staff
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Professor of Sociology and Anthropology
Section Head

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James Howe, PhD
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Jean Elizabeth Jackson, PhD
Professor of Anthropology

Associate Professor
Stefan Helmreich, PhD
Associate Professor of Anthropology

Assistant Professor
Erica C. James, PhD
Assistant Professor of Anthropology

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**Bachelor of Science in Anthropology/Course 21A**

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Science Requirement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>[three subjects may be satisfied by subjects in the Departmental Program]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

**Communication Requirement**

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H);
- 2 subjects designated as Communication Intensive in the Major (CI-M).

**PLUS Departmental Program**

Subject names below are followed by credit units, and by prerequisites if any.

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>21A.100 Introduction to Anthropology, 12, HASS-D</td>
<td>48</td>
</tr>
<tr>
<td>21A.109 Understanding Culture, 12, HASS-D</td>
<td></td>
</tr>
<tr>
<td>21A.110 Seminar in Anthropological Theory, 12*, HASS, CI-M</td>
<td></td>
</tr>
<tr>
<td>21A.112 Seminar in Ethnography and Fieldwork, 12*, HASS, CI-M</td>
<td></td>
</tr>
</tbody>
</table>

**Restricted Electives**

A coherent program of eight anthropology subjects which may include a pre-thesis tutorial and a thesis. The decision to write a thesis is made in consultation between the student and advisor.

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>90–96</td>
</tr>
</tbody>
</table>

**Departmental Program Units That also Satisfy the GIRs**

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(36)</td>
</tr>
</tbody>
</table>

**Unrestricted Electives**

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>72–78</td>
</tr>
</tbody>
</table>

**Total Units Beyond the GIRs Required for SB Degree**

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
</tr>
</tbody>
</table>

**Notes**

*Prerequisites are listed in the subject description.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
Established in 1999–2000, the program in Comparative Media Studies integrates the study of contemporary media (film, television, digital systems) with a broad historical understanding of older forms of human expression. The program embraces theoretical and interpretive principles drawn from the central humanistic disciplines of literary study, history, anthropology, art history, and film studies, but aims as well for a comparative synthesis that is responsive to the distinctive emerging media culture of the 21st century. Students explore the complexity of the media environment by learning to think across media, to see beyond the boundaries imposed by older medium-specific approaches to the study of audio-visual and literary forms.

The comparative and cross-disciplinary nature of both the graduate and undergraduate programs is embodied in a faculty drawn from Art and Architecture, Anthropology, Foreign Languages and Literatures, History, Literature, Music and Theater Arts, Philosophy, Writing and Humanistic Studies, Science, Technology, and Society, Media Arts and Sciences, Political Science, and Urban Studies and Planning.

**UNDERGRADUATE STUDY**

The undergraduate program—established in 1982 under its former name, Film and Media Studies—serves as preparation for advanced study in a range of scholarly and professional disciplines and also for careers in media or industry.

**Bachelor of Science in Comparative Media Studies/Course CMS**

The SB in Comparative Media Studies requires 10 subjects. Majors are required to take 21L.011 and 21L.015; CMS.400; one capstone subject; one additional CI-M subject; and five electives. It is strongly recommended that students take a practicum that includes a substantial hands-on component as one of their electives.

**Minor Program in Comparative Media Studies**

The minor program requires six subjects that reflect the comparative study of media, including 21L.011 or 21L.015; CMS.400; and four electives, including at least one chosen from the Special Topics subjects. Each minor designs his or her own plan of study in consultation with a field advisor.

**HASS Concentration**

The HASS Concentration requirement consists of four subjects that reflect the comparative study of media. Students are strongly encouraged to take at least one Special Topics subject to complete a concentration. Each concentrator designs his or her own plan of study in consultation with a field advisor.

**Joint Major**

The joint major requires eight elective subjects (including 21L.011 or 21L.015), CMS.400, one capstone subject (21L.016, 21F.015, or 21L.715) and one additional advanced-level subject, or seven elective subjects (including 21L.011 or 21L.015; CMS.400, and at least two seminar-level subjects), plus a pre-thesis tutorial and a thesis.

Undergraduate subjects include:

**Required Subjects**

21L.011 The Film Experience
21L.015 Introduction to Media Studies
CMS.400 Media Systems and Texts

**Capstone Courses**

*One of the following is required.*

CMS.605 Topics in International Media
21L.706 Studies in Film
21L.715 Media in Cultural Context

**CI-M Requirements**

(In addition to the capstone subject, one of the following courses, which can include a second capstone course, will fulfill the CI-M requirement.)

CMS.605 Topics in International Media
21L.706 Studies in Film
21L.708 Technologies of Humanism
21L.715 Media in Cultural Context
21W.785 Communicating Across Cyberspace

**Restricted Electives**

CMS.UR/URG Research in Comparative Media Studies
CMS.410 Popular Culture in the Age of Media Convergence
CMS.600 Topics in Comparative Media Studies

4.341 Introduction to Photography and Related Media
4.351 Introduction to Video
4.602 Modern Art and Mass Culture
21A.250 Storytelling: Women and Performance
21A.336 Marketing, Microchips, and McDonald’s: Debating Globalization
21A.337 Documenting Culture
21A.340 Technology and Culture
21A.348 Photography and Truth
21A.350 The Anthropology of Computing
21F.011 Topics in Indian Popular Culture
21F.013 Out of Ground Zero: Catastrophe and Memory
21F.027 Visualizing Cultures
21F.030 East Asian Culture: From Zen to Pop
21F.031 Topics in the Avant-Garde in Literature and Cinema
21F.035 Topics in Culture and Globalization
21F.036 Advertising and Popular Culture: East Asian Perspectives
21F.046 Modern Chinese Fiction and Cinema
21F.052 French Film Classics
21F.055 Media in Weimar and Nazi Germany
21F.056 Visual Histories: German Cinema 1945 to Present
21F.062 The City is a Woman: Modernity and Gender
21F.065 Japanese Literature and Cinema
21F.067 Cultural Performances of Asia
21F.341 Contemporary French Film and Social Issues (taught in French)
21H.206 American Consumer Culture
21H.546 World War II in Asia: Film, Fantasy, Fact
21L.012 Forms of Western Narrative
21L.421 Comedy
21L.430 Popular Narrative*
21L.432 Understanding Television
21L.433 Film Styles and Genres
21L.434 Science Fiction
21L.435 Literature and Film
21L.486 Twentieth-Century Drama
21L.489/21W.765 Interactive and Non-Linear Narrative: Theory and Practice
21M.283 Musicals of Screen and Stage
21M.284 Film Music
21M.775 Hip Hop
21M.846 Topics in Performance Studies (meets with CMS.600 and CMS.998)
21W.749 Documentary Photography and Photojournalism: Still Images of a World in Motion
21W.785 Communicating in Cyberspace
24.209 Philosophy in Film and Other Media
24.213 Philosophy of Film
MAS.450 Holographic Imaging
STS.085 Ethics and the Law on the Electronic Frontier

*when topic is applicable

Special Topics in Comparative Media Studies
(The following are considered to be advanced-level subjects in Comparative Media Studies.)
CMS.605 Topics in International Media
CMS.610 Media Industries and Systems
CMS.THT Pre-Thesis in Comparative Media
CMS.THU Undergraduate Thesis in Comparative Media
11.127 Computer Modeling for Investigation and Education
4.366 Advanced Projects in Visual Arts*
21H.418 From Print to Digital: Technologies of the Word, 1450–Present
21L.706 Studies in Film
21L.707 Problems in Cultural Interpretation*
21L.708 Technologies of Humanism
21L.715 Media in Cultural Context
MAS.849 Special Topics in Multimedia Production
21W.722 Advanced Workshop in Digital Poetry

*when topic is applicable

GRADUATE STUDY

The graduate program comprises a two-year course of study leading to a Master of Science in Comparative Media Studies. The program aims to prepare students for careers in fields such as journalism, teaching and research, government or public service, museum work, information science, corporate consulting, media industry marketing and management, and educational technology.

Students normally take three subjects per term, for a total of 12 subjects. All students take three introductory seminars (Media Theories and Methods I and II, and Major Media Texts) during their first year, as well as CMS.950, a workshop subject that offers hands-on experience in

Bachelor of Science in Comparative Media Studies/Course CMS

General Institute Requirements (GiRs)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
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<td>Science Requirement</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement (four subjects may be satisfied by subjects in the Departmental Program)</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Total GIR Subjects Required for SB Degree 17

Communication Requirement

The program includes a Communication Requirement of 4 subjects:

2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program

Subject names below are followed by credit units, and by prerequisites, if any

Required Subjects

[21L.015] The Film Experience, 12, HASS-D, CI-H
[21L.025] Introduction to Media Studies, 12, HASS-D, CI-H
CMS.400 Media Systems and Texts, 12, HASS, one subject in CMS or permission of instructor

Choose one of the following as a capstone subject:

[21L.706] Studies in Film, 12, HASS, CI-M, two subjects in CMS and/or Literature or permission of instructor
[21L.715] Media in Cultural Context, 12, HASS, CI-M, two subjects in CMS and/or Literature or permission of instructor

CMS.605 Topics in International Media, 12, HASS, CI-M, two subjects in CMS or permission of instructor

In addition to the capstone subject, one of the following subjects, which can include a second capstone, will fulfill the CI-M requirement:

[21L.706] Studies in Film, 12, HASS, CI-M, two subjects in CMS and/or Literature or permission of instructor
[21L.715] Media in Cultural Context, 12, HASS, CI-M, two subjects in CMS and/or Literature or permission of instructor
CMS.605 Topics in International Media, 12, HASS, CI-M, two subjects in CMS or permission of instructor

[21L.708] Technologies of Humanism, 12, HASS, two subjects in CMS and/or Literature or permission of instructor
[21W.785] Communicating in Cyberspace, 12, HASS

Restricted Electives

Students choose five restricted electives. It is also recommended that students take one practicum, or subject with substantial hands-on component. Qualified students may, with departmental approval, substitute a thesis and a pre-thesis for two subjects.

Departmental Program Units That also Satisfy the GIRs 51–60

Unrestricted Electives

(48)

Total Units Beyond the GIRs Required for SB Degree 180

Notes

Starting in Fall 2003, students may pursue an SB degree in Comparative Media Studies. This new undergraduate degree program is authorized by the Committee on the Undergraduate Program, and will be reviewed in Fall 2008. In the event that the new degree program is not approved for permanent status by the Faculty in academic year 2008–2009, accommodations will be made for any student enrolled in the major prior to Fall 2008 to complete the degree program. Students may contact the director of Comparative Media Studies, Henry Jenkins, for more information.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
media. Elective subjects are drawn from three categories: theory and criticism; history, society, politics; and case studies. The required thesis may take a variety of forms, including traditional expository prose, but students are encouraged to choose projects that exploit other appropriate media.

Students may enter the program with a degree from a wide range of undergraduate majors, including the liberal arts, the social sciences, journalism, computer science, and management.

Graduate subjects include:

Proseminars
CMS.790  Media Theories and Methods I
CMS.791  Media Theories and Methods II
CMS.796  Major Media Texts
CMS.801  Media in Transition

theory and Criticism
CMS.830  Studies in Film (meets with 21L.706)
CMS.835  Photography and Truth (meets with 21A.348)
CMS.840  Literature and Film (meets with 21L.435)
CMS.845  Interactive and Non-Linear Narrative (meets with 21L.489 and 21W.765)
CMS.851  Feeling and Imagination in Art, Science, and Technology (meets with 24.262)

History, Society, Politics
CMS.871  Media in Cultural Context (meets with 21L.715)
CMS.872  Topics in International Media (meets with 21F.015)
CMS.874  Visualizing Cultures (meets with 21H.917/21F.027/21F.590)
CMS.876  History of Media and Technology
CMS.888  Advertising and Popular Culture: East Asian Perspectives (meets with 21F.036)

Case Studies
CMS.910  Literature and Technology (meets with 21L.708)
CMS.915  Understanding Television (meets with 21L.432)
CMS.917  Documenting Culture (meets with 21A.337)
CMS.920  Popular Narrative (meets with 21L.430)
CMS.921  Popular Culture in the Age of Media Convergence (meets with CMS.410)
CMS.922  Media Industries and Systems (meets with CMS.610)
CMS.925  Film Music (meets with 21M.284)
CMS.935  Documentary Photography and Photojournalism: Still Images of a World in Motion (meets with 21W.749)

Additional subjects
CMS.950  Workshop I
CMS.980  Master’s Thesis
CMS.990  Colloquium in Comparative Media
CMS.992  Portfolio in Comparative Media
CMS.993  Teaching in Comparative Media
CMS.995  Research in Comparative Media
CMS.998  Topics in Comparative Media
CMS.999  Topics in Comparative Media

For detailed descriptions of graduate subjects in comparative media studies, see CMS.790–CMS.999 in Part 3.

Inquiries
For more information on the undergraduate and graduate programs in Comparative Media Studies, contact the CMS Office, Room 14N-207, MIT, 617-253-3599; fax 617-258-5133; cms@mit.edu.

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Directors
Henry Jenkins III, PhD
Peter de Florez Professor of Humanities
Professor of Comparative Media Studies and Literature

William Uricchio, PhD
Professor of Comparative Media Studies

Steering Committee*
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Professor of Literature
Section Head, Literature

James Paradis, PhD
Robert M. Metcalfe Professor of Writing
Program Head, Writing and Humanistic Studies

Janet Sonenberg, MFA
Professor of Theater Arts
MacVicar Faculty Fellow
Section Head, Music and Theater Arts

Jing Wang, PhD
S. C. Fang Professor of Chinese Language and Culture
Section Head, Foreign Languages and Literatures

*The Comparative Media Studies program is jointly administered by three Humanities sections: Literature, Foreign Languages and Literatures, and Writing and Humanistic Studies. Though the program has no direct appointments, more than thirty faculty members from across the School of Humanities, Arts and Social Sciences regularly teach in the program.
Economics is the study of all those aspects of individual and social activities related to the choice, production, distribution, and consumption of goods and services. In relation to these decisions, economics is concerned with the behavior and interaction of individuals, private firms, and other institutions and government agencies. Thus, economics contributes to the understanding of many important social problems: changes in efficiency and productivity, fluctuations in the overall levels of economic activity and employment, inflation, the effects of government deficits, the growth and decline of industries, changes in foreign exchange rates, increases in international indebtedness, and the behavior of the centrally planned and less developed countries.

Subjects are offered in the major areas of economics: theoretical and applied analysis at the levels of the individual consumer, the firm, and the industry, as well as aggregate economic activity, industrial organization and health economics, econometrics, public finance, urban economics, labor economics and industrial relations, behavioral economics, international trade and finance, economic history, and economic development.

UNDERGRADUATE STUDY

Bachelor of Science in Economics/ Course 14

Course 14, leading to the Bachelor of Science in Economics, combines training in technical economics with opportunities for a broad and balanced undergraduate education. Students may choose from a diversified group of undergraduate subjects and are encouraged to engage in independent research.

The aims of the undergraduate degree program are threefold: to give students a firm grounding in modern economic theory and a basic understanding of economic processes; to provide a descriptive knowledge of the US and world economies; and to develop in students the capabilities for quantitative analysis and independent thought. These aims correspond roughly to the requirements in the Course 14 program of theory, electives, statistics and econometrics, and research.

The requirements allow substantial freedom for students in designing individual programs within economics and balancing the programs with subjects in other disciplines. The large amount of unrestricted elective time encourages students to shape programs close to their own needs and interests. Students may select programs that concentrate on economics and other social sciences or may combine economics with other fields. They may emphasize the relation of economics and technology by choosing their free electives in engineering and science, or they may combine their studies in economics with subjects in history and the other humanities.

The successful completion of the degree program prepares students for further study in economics or for careers in business administration and finance, consulting, law and related fields, and public policy.

Although there are several satisfactory alternative subject sequences, students who by the end of their second year have taken 14.01 Principles of Microeconomics and 14.02 Principles of Macroeconomics can follow a program that permits considerable depth in electives in their third and fourth years. The student can complete 14.04 Intermediate Microeconomic Theory and 14.05 Intermediate Applied Macroeconomics, 14.30 Introduction to Statistical Method in Economics, and 14.32 Econometrics in the third year. This program satisfies the prerequisites for all subjects, including 14.33, and prepares students for research on their thesis and in other elective subjects in their fourth year.

The department specifies one Restricted Elective in Science and Technology (REST) Requirement subject and one laboratory subject, and strongly recommends that students take additional subjects in mathematics, if professionally interested in economics.

Minor Program in Economics

The objective of the minor program is to extend the understanding of economic issues beyond the level of the concentration. This is done through specialized analytical subjects and elective subjects that provide an extensive treatment of economic issues in particular areas.

The Minor Program in Economics consists of six subjects arranged into three levels of study: Tier I Three subjects:

- 14.01 Principles of Microeconomics*
- 14.02 Principles of Macroeconomics*
- and either
- 14.30 Introduction to Statistical Method in Economics
- or
- 18.05 Introduction to Probability and Statistics

Tier II One subject from the following three:

- 14.03 Microeconomic Theory and Public Policy
- 14.04 Intermediate Microeconomic Theory
- 14.05 Intermediate Applied Macroeconomics

Tier III Two subjects

Two elective undergraduate subjects chosen from the fields of applied economics. A list of specific subjects is available in the Economics Department Office, E52-391.

*Note: Under no circumstances may a student complete a minor with fewer than six subjects. Any student who receives permission from the Economics Department to skip 14.01 and/or 14.02 and take a higher-level subject must take replacement subject(s) for 14.01/14.02.

In addition to its broad undergraduate program, the department offers a graduate program leading to the PhD in economics.

GRADUATE STUDY

Entrance Requirements for Graduate Study

The Department of Economics specifies the following prerequisites for graduate study in economics: one full year of college mathematics, including at least one term of calculus; at least six term subjects in English, history, and other humanities or social science subjects (not in the candidate’s own professional field) equivalent to those included in the undergraduate curriculum at MIT; and an appreciable number of professional subjects in economics for those qualified students who have majored in fields other than economics. Applicants for admission who have deficiencies in entrance requirements should consult with the department about programs to remedy such deficiencies.
**Bachelor of Science in Economics/Course 14**

**General Institute Requirements (GIRs)**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td></td>
</tr>
<tr>
<td>(three subjects can be satisfied by subjects in the Departmental Program)</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>8</td>
</tr>
<tr>
<td>(one subject can be satisfied by 14.30 in the Departmental Program)</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>2</td>
</tr>
<tr>
<td>(can be satisfied by 14.33 in the Departmental Program)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total GIR Subjects Required for SB Degree**

17

**Communication Requirement**

The program includes a Communication Requirement of 4 subjects: 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and 2 subjects designated as Communication Intensive in the Major (CI-M).

**PLUS Departmental Program**

**Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)**

**Required Subjects**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.01 Principles of Microeconomics, 12, HASS</td>
<td>12</td>
</tr>
<tr>
<td>14.02 Principles of Macroeconomics, 12, HASS</td>
<td>12</td>
</tr>
<tr>
<td>14.04 Intermediate Microeconomic Theory, 12, HASS</td>
<td>18.02</td>
</tr>
<tr>
<td>14.05 Intermediate Applied Macroeconomics, 12, HASS, CI-M; 14.02</td>
<td>12</td>
</tr>
<tr>
<td>14.30 Introduction to Statistical Method in Economics</td>
<td>18.02</td>
</tr>
<tr>
<td>14.32 Econometrics, 12, 14.30</td>
<td>12</td>
</tr>
<tr>
<td>14.33 Economics Research and Communication, 12, LAB, CI-M; 14.32</td>
<td>12</td>
</tr>
<tr>
<td>14.THU Thesis (15 units), 14.33</td>
<td>15</td>
</tr>
</tbody>
</table>

**Restricted Electives**

Elective subjects in economics

60

**Departmental Program Units That also Satisfy the GIRs**

(60)

**Unrestricted Electives**

81–84

**Total Units Beyond the GIRs Required for SB Degree**

180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

**Notes**

(1) No more than three subjects in economics may be used for the Humanities, Arts, and Social Sciences Requirement.

(2) Or an approved alternative in statistics.

(3) May be replaced by an additional elective subject in economics.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

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**Master of Science in Economics**

Under special circumstances, admission may be granted to candidates seeking the Master of Science degree. The general requirements for the SM are given in the section on Graduate Education.

**Doctor of Philosophy**

A candidate for the doctorate must demonstrate a mastery of economic theory, including both microeconomics and macroeconomics, and four other fields of study; achieve a specified level of competence in economic history and econometrics; submit and defend a dissertation that represents a contribution to knowledge; and be in residence for a minimum of two years. Two of the four fields, including economic theory, are covered by the written General Examination. Two minor fields may each be satisfied by one year of coursework. The four major and minor elective fields may be chosen from advanced economic theory, econometrics, economic development, economic history, finance, industrial organization, international economics, labor economics, monetary economics, public economics, and urban economics.

There is no required minimum number of graduate subjects in the department. However, candidates ordinarily need two full academic years of study to prepare adequately for the General Examinations and to meet the other pre-thesis requirements. The doctoral thesis must be written in residence, which typically requires two years of research.

**Economics and Urban Studies**

A doctoral program offered jointly by the Departments of Economics and Urban Studies and Planning at MIT integrates the analytic emphasis of economics with the institutional and policy orientation of urban studies. Students desiring to enter the program must be admitted to both departments and then explicitly to the joint degree program. Specific requirements for economics are the same as for the economics PhD with only two major fields and one minor, instead of two major and two minor fields; and economic history is not required. The specific requirements for urban studies are the same as for the PhD except for substitution of an economics general examination field for one of the required urban studies fields. One dissertation
is required with acceptance by both departments. The program is administered by an informal Standing Committee. Further information is available from Professor William C. Wheaton, Room E52-252B, MIT, 617-253-1723.

Teaching and Research Assistantships
A limited number of students are supported by scholarship and fellowship grants, as well as by teaching and research assistantships. Typically, the assistantships are available only to students who have passed their general examinations, but in special circumstances research assistantships may be held by second-year students.

Inquiries
Additional information concerning academic programs in the department, admissions, and financial aid may be obtained by writing to the graduate administrator, Department of Economics, Room E52-391D, MIT, 77 Massachusetts Ave, Cambridge, MA 02139-4307, 617-253-8787.

Faculty and Teaching Staff
Faculty and Teaching Staff
James M. Poterba, DPhil
Mitsui Professor of Economics
Head of Department
Jonathan Gruber, PhD
Professor of Economics
Associate Head of Department

Professors
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Charles P. Kindleberger Professor of Economics
(On leave)
Joshua Angrist, PhD
Professor of Economics
Abhijit Banerjee, PhD
Ford International Professor of Economics
Olivier Blanchard, PhD
Class of 1941 Professor of Economics
Ricardo J. Caballero, PhD
Ford International Professor of Economics
Dora Costa, PhD
Professor of Economics
(On leave)
Peter A. Diamond, PhD
Professor of Economics
Institute Professor
Esther Dufo, PhD
Professor of Economics
(On leave)
Glenn D. Ellison, PhD
Professor of Economics
Robert S. Gibbons, PhD
Sloan Distinguished Professor of Management and Economics
Michael Greenstone, PhD
3M Professor of Environmental Economics
Jeffrey E. Harris, MD, PhD
Professor of Economics
Jerry A. Hausman, DPhil
John and Jennie S. MacDonald Professor of Economics
(On leave)
Bengt R. Holmström, PhD
Paul A. Samuelson Professor of Economics
(On sabbatical)
Paul L. Joskow, PhD
Elizabeth and James Killian Professor of Economics and Management
Whitney K. Newey, PhD
Jane Berkowitz Carlton and Dennis William Carlton Professor of Economics
Michael J. Piore, PhD
David W. Skinner Professor of Political Economy
Nancy L. Rose, PhD
Professor of Economics
Stephen Ross, PhD
 Franco Modigliani Professor of Finance and Economics
 Richard L. Schmalensee, PhD
 Gordon Y Billard Professor of Management and Economics
 Dean, Sloan School of Management
 James Snyder, PhD
 Professor of Political Science and Economics
 Peter Temin, PhD
 Elisha Gray II Professor of Economics
 Lester C. Thurow, PhD
 Jerome and Dorothy Lemelson Professor of Management and Economics
 William C. Wheaton, PhD
 Professor of Economics and Urban Studies
 Director for Research, Center for Real Estate

Associate Professors
George-Marios Angeletos, PhD
Associate Professor of Economics
David Autor, PhD
Associate Professor of Economics
(On leave)
Victor Chernozhukov, PhD
Castle Krob Career Development Associate Professor of Economics
(On leave)
Xavier Gabaix, PhD
Rudi Dornbusch Career Development Associate Professor of Economics
Muhamet Yildiz, PhD
Pentti J. K. Kouri Career Development Associate Professor

Assistant Professors
Haluk Ergin, PhD
Assistant Professor of Economics
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Amy Finkelstein, PhD
Assistant Professor of Economics
Mikhail Golosov, PhD
Assistant Professor of Economics
Sergei Izmalkov, PhD
Assistant Professor of Economics
Panle Jia, PhD
Assistant Professor of Economics
Iván Werning, PhD
Assistant Professor of Economics

Senior Lecturer
Sara Fisher Ellison, PhD
Visiting Professors

Pol Antras, PhD
Visiting Assistant Professor of Economics

Mathias Dewatripont, PhD
Visiting Professor of Economics

Graham Elliott, PhD
Visiting Professor of Economics

Ernst Fehr, PhD
Visiting Professor of Economics

Garance Genicot, PhD
Visiting Professor of Economics

Francesco Giavazzi, PhD
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Lorenz Goette, PhD
Visiting Assistant Professor of Economics

Jörn-Steffen Pischke, PhD
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Jean Tirole, PhD
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Abraham J. Siegel, PhD
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Professors Emeriti

Morris A. Adelman, PhD
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Robert L. Bishop, PhD
Professor of Economics, Emeritus

E. Cary Brown, PhD
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Richard S. Eckaus, PhD
Ford International Professor of Economics, Emeritus

Stanley Fischer, PhD
Professor of Economics, Emeritus

Frank Fisher, PhD
Jane Berkowitz Carlton and Dennis William Carlton Professor of Economics, Emeritus

Jerome Rothenberg, PhD
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Gordon Y Billard Fellow
Institute Professor, Emeritus

Robert M. Solow, PhD, LLD, DLH
Professor of Economics, Emeritus

Institute Professor, Emeritus
The Foreign Languages and Literatures Section offers a variety of programs. There are subject sequences in Chinese, French, German, Japanese, and Spanish languages and literatures taught in the original; a subject sequence on literature in English translation (SILC); studies in bilingualism; and a comprehensive program in English Language Studies.

The Foreign Languages and Literatures curriculum is arranged in three tiers. Fundamental language subjects familiarize students with the principles of the language in both its spoken and written forms, and introduce them to the culture of the country where the language is spoken. Levels III and IV language subjects provide review and refinement of grammar, study of more difficult reading matter with cultural and literary content, and include compositions and discussions in the foreign language.

Subjects in language, literature, and culture are conducted in the foreign language. They introduce students to the form and content of foreign literatures and of foreign cultures and societies. These subjects also offer the opportunity to develop more refined communication skills in the language. Advanced subjects, conducted in the foreign language, encourage students to explore the cultural history of the particular country in which the language is spoken.

Offerings in Studies in International Literatures and Cultures (SILC), taught in English, give students both a specific and comparative focus on foreign cultures.

Concentrations are available in a given language, literature, or culture in the original language or in English. Concentrations should be arranged on an individual basis in consultation with a designated advisor in each language group.

The Minor Programs in Chinese, French, German, Japanese, and Spanish lead students who have already reached an intermediate level of proficiency into more advanced study of the language, literature, and culture. Note that language levels I and II do not count toward the minor. Also note that, unlike other minor programs in HASS, the minor advisor in each of these languages can, at his or her discretion, approve a minor in which MIT subjects comprise at least one-third of the subjects of the program. However, this exception to the general HASS Minor Requirement is only allowed in those cases in which students have received transfer credits equal to four subjects through study abroad in a country where the language of the minor is the dominant tongue.

**Bachelor of Science in Foreign Languages and Literatures/Course 21F**

Program I in French Studies and Program II in Spanish Studies are designed to provide: competence in reading, writing, and speaking; general knowledge of French or Spanish culture and literature; and advanced subjects in literature, film, and cultural studies.

For either option, each student designs a program in consultation with an advisor in order to meet individual interests, abilities, and goals. However, all majors reflect a balance of historical, geographical, cultural, and linguistic competence.

**Minor Programs**

The Minor Program in Chinese typically consists of six subjects arranged into three levels of study as follows:

- **Tier I** Two language subjects at the intermediate level:
  - 21F.103 Chinese III (Regular)
  - 21F.109 Chinese III (Streamlined) or
  - 21F.104 Chinese IV (Regular) or
  - 21F.110 Chinese IV (Streamlined)

- **Tier II** Two language subjects at the advanced level:
  - 21F.105 Chinese V (Regular) or
  - 21F.113 Chinese V (Streamlined) or
  - 21F.106 Chinese VI (Regular)

Students in the Streamlined sequence of subjects (as opposed to Regular) should consult with the minor advisor about the special options for them to fulfill the Tier II requirement.

Two subjects in Chinese literature, history, or culture, at least one of which must be a Chinese Language Option subject, i.e. 21F.190, 21F.191, or 21F.192. The Chinese Language Option subjects meet with the three subjects 21F.036, 21F.046, and 21H.560, respectively, and include some assignments that require reading and writing in Chinese.

- **Tier III**
  - 17F.47 Chinese Language Studies
  - 17F.51 Political Economy of Chinese Reform
  - 21F.030 East Asian Culture: From Zen to Pop

**Minor Program in French**

- **Tier I**
  - 21F.038 The Cultural Politics of Contemporary China
  - 21F.044 Traditional Chinese Literature
  - 21F.045 Kung-Fu Cinema: Transnational Perspectives

- **Tier II**
  - 21F.046/21F.192 Modern Chinese Fiction and Cinema
  - 21H.504 East Asia in the World: 1500–2000
  - 21H.560/21F.191 Smashing the Iron Rice Bowl: Chinese East Asia

- **Tier III**
  - 21H.580 From Silk Road to the Great Game: China, Russia, and Central Asia, 500–2000 A.D.

**Minor Program in Spanish**

- **Tier I**
  - 21F.030 East Asian Culture: From Zen to Pop
  - 21F.038 The Cultural Politics of Contemporary China
  - 21F.044 Traditional Chinese Literature

- **Tier II**
  - 21F.045 Kung-Fu Cinema: Transnational Perspectives
  - 21H.504 East Asia in the World: 1500–2000
  - 21H.560/21F.191 Smashing the Iron Rice Bowl: Chinese East Asia

- **Tier III**
  - 21H.580 From Silk Road to the Great Game: China, Russia, and Central Asia, 500–2000 A.D.
Bachelor of Science in Foreign Languages and Literatures/Course 21F

General Institute Requirements (GIRs) Subjects
Science Requirement 6
Humanities, Arts, and Social Sciences Requirement [three subjects may be satisfied by subjects in the Departmental Program] 8
Restricted Electives in Science and Technology (REST) Requirement 2
Laboratory Requirement 1
Total GIR Subjects Required for SB Degree 17

Communication Requirement
The program includes a Communication Requirement of 4 subjects:
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program Units
Subject names below are followed by credit units, and by prerequisites if any

Program 1: French Studies
Prerequisite subjects: 21F.301, 21F.302 (24)
Required Subjects 42
21F.304 French IV, 12, HASS-D Language Option, 21F.303
To satisfy the requirement that students complete two Communication Intensive subjects in the major, students must take 21F.306 and 21F.307. Registration for 21F.306 and 21F.307 must be simultaneous with one of the following subjects: 21F.308, 21F.310, 21F.311, 21F.312, 21F.315, 21F.320, 21F.336, 21F.341, 21F.343, 21F.345, 21F.346, or 21F.347.
Restricted Electives 90
A coherent program of 8 subjects beyond French II from the French curriculum, which may include a pre-thesis tutorial and a thesis.

Program 2: Spanish Studies
Prerequisite subjects: 21F.701, 21F.702 (24)
Required Subjects 42
21F.704 Spanish IV, 12, HASS-D Language Option, 21F.703
To satisfy the requirement that students complete two Communication Intensive subjects in the major, students must take 21F.708 and 21F.709. Registration for 21F.708 and 21F.709 must be simultaneous with one of the following subjects: 21F.716, 21F.717, 21F.730, 21F.731, 21F.735, 21F.736, 21F.738, 21F.740, or 21F.742.
Restricted Electives 90
A coherent program of 8 subjects beyond Spanish II from the Spanish curriculum, which may include a pre-thesis tutorial and a thesis.

Departmental Program Units That also Satisfy the GIRs
(36)
Unrestricted Electives
Program 1 48
Program 2 48
Total Units Beyond the GIRs Required for SB Degree 180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both. For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

The Minor Program in German consists of six subjects arranged into three levels of study as follows:

Tier I Two subjects or fewer depending on demonstrated level of entering competence
21F.403 German III
21F.404 German IV

Tier II Two subjects or three subjects from the intermediate subjects in German language, literature, and culture.
21F.405 Germany Today: Intensive Study of German Language and Culture
21F.409 Opening the Text: Reading, Writing and Performing in German
21F.410 Professional Communication in German
21F.412 German Literature: An Introduction

Tier III Two or three subjects from the intermediate subjects in German language, literature, and culture.
21F.405 Germany Today: Intensive Study of German Language and Culture
21F.409 Opening the Text: Reading, Writing and Performing in German
21F.410 Professional Communication in German
21F.412 German Literature: An Introduction

The Minor Program in Japanese consists of six subjects arranged into three levels of study as follows:

Tier I Two language subjects at the intermediate level
21F.503 Intermediate Japanese I
21F.504 Intermediate Japanese II

Tier II Two language subjects at the advanced level
21F.505 Advanced Japanese I
21F.506 Advanced Japanese II

Tier III Two subjects in Japanese literature, history, or culture, at least one of which must be a Japanese Language Option subject, i.e., 21F.590, 21F.591, 21F.592, 21F.593, 21F.594, or 21F.595. The Japanese Language Option subjects meet with the six subjects, 21F.027J, 21F.039, 21F.064, 21F.065, 21F.066, and 21F.067J, respectively, and include some assignments that
require reading and writing in Japanese.

17.433 International Relations of East Asia
17.486 Japan and East Asian Security
17.537 Politics and Policy in Contemporary Japan
17.543 Japanese Politics and Society
21F.027J/21F.590 Visualizing Cultures
21F.030 East Asian Cultures: From Zen to Pop
21F.064/21F.592 Introduction to Japanese Culture
21F.065/21F.593 Japanese Literature and Cinema
21F.066/21F.594 Japan in Real Time
21F.067J/21F.595 Cultural Performances of Asia
21H.521 Ancient Japan and Courtly Society
21H.522 Japan in the Age of the Samurai: History and Film
21H.523 Emergence of the Modern Japanese State: 1800–1952
21H.546 World War II in Asia: Film, Fantasy, Fact

Please also refer to HASS Minors in Regional Studies, which include Applied International Studies, East Asian Studies, European Studies, Latin American Studies, Middle Eastern Studies, African and African Diaspora Studies, and Russian Studies.

Other Degree Programs
A degree program is offered in German (Course 21). Joint degree programs are offered in French, German, and Spanish, and include majors in combination with a field in engineering or science (21E, 21S). See the Department of Humanities section for further information.

Further information on subjects and programs may be obtained from the Foreign Languages and Literatures Section Office, Room 14N–305, 617–253–4771.

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Lecturer
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Director of Spanish Language Studies
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Ikue Shingu, MA
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Lecturer in Chinese

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Professors Emeriti
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Robert Emmet Jones, PhD
Professor of French and Humanities, Emeritus

Margaret Zaroodny Freeman, SM
Associate Professor of Russian, Emerita

James Wesley Harris, PhD
Professor of Spanish and Linguistics, Emeritus
History is the study of the recorded past. Since interest in the past is closely linked with a desire to understand the present, the history curriculum at MIT is tailored in part to put the modern world in historical perspective. Subjects explore the social, economic, and political transformations that shape the present; and efforts are made to suggest where traditional assumptions remain in present-day politics, society, and culture.

The curriculum seeks to encourage both an understanding of the human past and the development of skills necessary to express that knowledge effectively.

**Bachelor of Science in History/ Course 21H**

The program leading to the degree of Bachelor of Science in History is designed to encourage students to discover and reconstruct the past, to confront and understand the complexity of past human behavior for itself, and to inform their sense of the historical present. The curriculum includes the selection of at least one subject taken from the curriculum's HASS-D offerings, as well as one 21H elective seminar. Students are expected to take six additional subjects of their own choice, selected in consultation with a major advisor. These must include subjects drawn from at least two geographical areas, as well as one pre-modern (before 1700) and one modern subject.

During the junior year, the history major is required to take the Seminar in Historical Methods, which is intended to develop skills for independent research and writing, followed in the senior year by a Thesis Tutorial, and either a second major essay or a senior thesis. Students are expected to take six additional subjects of their own choice, selected in consultation with a major advisor. These must include subjects drawn from at least two geographical areas, as well as one pre-modern (before 1700) and one modern subject.

For a listing of available subjects, consult the History Office, Room E51-285, 617-253-4965.

**Concentration in History**

The Concentration in History will consist of three subjects, at least one and not more than two of which shall be selected from the 21H HASS-D designated offerings.

**Minor in Applied International Studies**

A range of subjects in history can fulfill requirements for the interdisciplinary Minor in Applied International Studies. For more information about this minor, see the program description under Political Science in Part 2.

**Joint Degree Programs**

Joint degree programs are offered in history in combination with a field in engineering or science (21E, 21S). See the joint major programs listed under Humanities.

Subjects in history are numbered 21H.001 through 21H.999 in Part 3. Further information on subjects and programs may be obtained from the History Office, Room E51-285, 617-253-4965.

**Minor Program in History**

The goal of the minor program is to lead the student from basic survey subjects into more focused studies of individual countries or periods of time, and to encourage thinking about broader analytical and comparative issues in historical study.

The Minor Program in History consists of six subjects, which must include:

- At least one 21H subject that is designated HASS-D
- At least one 21H elective seminar
- Three undergraduate elective subjects from the history curriculum
- 21H.931 Seminar in Historical Methods
- At least two temporal periods—one pre-modern (before 1700) and one modern—to be covered by the five subjects other than 21H.931

For a listing of available subjects, consult the History Office, Room E51-285, 617-253-4965.

**FACULTY AND STAFF**

**Faculty and Teaching Staff**

Anne E. C. McCants, PhD
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**Professors**

John W. Dower, PhD
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Meg Jacobs, PhD
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Elizabeth A. Wood, PhD
Associate Professor of History
(On leave, spring)
## Bachelor of Science in History/Course 21H

### General Institute Requirements (GIRs)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement [three subjects can be satisfied by subjects in the Departmental Program]</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

### Communication Requirement

The program includes a Communication Requirement of 4 subjects:
- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

### PLUS Departmental Program

<table>
<thead>
<tr>
<th>Subject names below are followed by credit units, and by prerequisites if any</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Subjects</td>
<td></td>
</tr>
<tr>
<td>One 21H HASS-D subject (12 units)</td>
<td>57–60</td>
</tr>
<tr>
<td>One 21H seminar subject (9–12 units)</td>
<td></td>
</tr>
<tr>
<td>21H.931 Seminar in Historical Methods, 12*, CI-M; HASS (required during junior year)</td>
<td></td>
</tr>
<tr>
<td>21H.THT History Pre-Thesis Tutorial, 12</td>
<td></td>
</tr>
<tr>
<td>21H.THU History Thesis, 12, CI-M; 21H.THT</td>
<td></td>
</tr>
</tbody>
</table>

### Restricted Electives

A coherent program of six subjects from the history curriculum; and three related subjects from a second HASS discipline.

### Departmental Program Units That also Satisfy the GIRs

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

### Unrestricted Electives

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>48–72</td>
</tr>
</tbody>
</table>

### Total Units Beyond the GIRs Required for SB Degree

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
</tr>
</tbody>
</table>

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

### Notes

*Prerequisites are listed in the subject description.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
The Department of Humanities consists of six autonomous sections and programs, each with its own headquarters: Anthropology, Foreign Languages and Literatures, History, Literature, Music and Theater Arts, and Writing and Humanistic Studies.

In addition to the degrees offered in the six sections, other undergraduate degree programs are available in Course 21, either in combination with a field in engineering or science (Course 21E, Course 21S) or as full majors (major department, Course 21), described later in this section. Students interested in any of these degree programs should consult an advisor in the field, as well as the section or program office.

**Bachelor of Science in Humanities/Course 21**

**General Institute Requirements (GIRs)**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
</tr>
<tr>
<td>Social Sciences Distribution subjects can be satisfied by subjects in the Departmental Program</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td>17</td>
</tr>
</tbody>
</table>

**Communication Requirement**
The program includes a Communication Requirement of 4 subjects:
- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H);
- 2 subjects designated as Communication Intensive in the Major (CI-M).

**PLUS Departmental Program**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted Electives</td>
<td>126–162</td>
</tr>
</tbody>
</table>

**German**
8 elective subjects in the field (which may include a pre-thesis and a thesis), plus a four-subject cluster. (50)
To satisfy the requirement that students complete two Communication Intensive subjects in the major, students must take 21F.406 and 21F.407. Registration for 21F.406 and 21F.407 must be simultaneous with one of 21F.412, 21F.414, 21F.415, 21F.416, or 21F.418.

**Major Departures**
The restricted electives for the major departure fields are determined in consultation with the faculty advisor in the chosen field.
Each major departure program must include two Communication Intensive major subjects, usually chosen from the subjects designated as CI-M for major programs in adjacent disciplines.

**Departmental Program Units That also Satisfy the GIRs**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>(27–36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted Electives</td>
<td>45–90</td>
</tr>
</tbody>
</table>

**Total Units Beyond the GIRs Required for SB Degree**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>180</th>
</tr>
</thead>
</table>

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

**Notes**

- Only one subject used to meet the distribution element of the Humanities, Arts, and Social Sciences Requirement may be counted toward the humanities component of these degree programs.
- The cluster is usually formed within a single second discipline of the humanities, arts, or social sciences. In special cases, it may draw together subjects from different disciplines to form a coherent grouping.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

**Major Departure**

**Bachelor of Science in Humanities/Course 21**
The Bachelor of Science in Humanities degree provides an option for students who wish to pursue their humanistic studies extensively and at an advanced level. This degree is received by students majoring in German or completing a Course 21 major departure. The major departure is a major by special arrangement, requiring approval by the Dean of the School of Humanities, Arts, and Social Sciences, in one of the following fields:

American Studies
Ancient and Medieval Studies
East Asian Studies
Latin American Studies
Psychology
Russian Studies
Theater Arts
Women’s Studies
Humanities and Engineering/Science

**Bachelor of Science in Humanities and Engineering/Course 21E**

**Bachelor of Science in Humanities and Science/Course 21S**

These joint major programs combine humanities with scientific/engineering studies. Groups of subjects from the humanistic and technical areas are conjoined to yield a basic command of each mode of inquiry. One part is a selection from the undergraduate degree curriculum of a science or engineering department approved by a faculty member in the field. The other part consists of subjects in a humanities field, chosen by the student in consultation with an advisor from the appropriate humanities faculty. In most cases, a senior thesis or sequence of advanced seminars is also required.

This arrangement yields a humanities program of considerable depth while allowing for continued serious commitment to a scientific or engineering interest. Available humanities fields include:

- American Studies
- Ancient and Medieval Studies
- Anthropology
- Comparative Media Studies
- East Asian Studies
- Foreign Languages and Literatures (in French, German, or Spanish)
- History
- Latin American Studies
- Literature
- Music
- Psychology
- Russian Studies
- Science, Technology, and Society
- Theater Arts
- Women’s Studies
- Writing (Creative, Expository, Science Writing, or Technical Communication)

---

**Bachelor of Science in Humanities and Engineering/Course 21E and Bachelor of Science in Humanities and Science/Course 21S**

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)(i)</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement [all but two Humanities, Arts, and Social Sciences Distribution subjects can be satisfied by subjects in the Departmental Program]</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td>17</td>
</tr>
</tbody>
</table>

**Communication Requirement**

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M). Each 21E and 21S program must include two CI-M subjects. Normally, students are expected to complete one CI-M from each area of study, usually chosen from the subjects designated as CI-M for the full major.

**PLUS Departmental Program**

<table>
<thead>
<tr>
<th>Restricted Electives</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropology</td>
<td>102–108</td>
</tr>
<tr>
<td>Foreign Languages and Literatures (in French, German, or Spanish)</td>
<td>81–102</td>
</tr>
<tr>
<td>History</td>
<td>81–102</td>
</tr>
<tr>
<td>Literature</td>
<td>96</td>
</tr>
<tr>
<td>Music</td>
<td>90–96</td>
</tr>
<tr>
<td>Writing: Creative or Expository</td>
<td>96–102</td>
</tr>
<tr>
<td>Writing: Science Writing or Technical Communication Studies</td>
<td>90–102</td>
</tr>
<tr>
<td>American Studies*(a)</td>
<td>B1–102</td>
</tr>
<tr>
<td>Ancient and Medieval Studies*(a)</td>
<td>B1–102</td>
</tr>
<tr>
<td>Comparative Media Studies</td>
<td>B1–102</td>
</tr>
</tbody>
</table>

*(a) Students may submit a request to the American Studies faculty advisor to substitute two classes in lieu of the pre-thesis and thesis.*

---

| American Studies*(a) | B1–102 |
| Ancient and Medieval Studies*(a) | B1–102 |
| Comparative Media Studies | B1–102 |

*(a) Students may submit a request to the American Studies faculty advisor to substitute two classes in lieu of the pre-thesis and thesis.*

---

*2006–2007*
Faculty advisors in each discipline help students to arrange programs suited to both their interests and professional objectives. Any one of these fields may be joined with any science or engineering field to form a major. Some combinations naturally lend themselves not only to an understanding of each field but also to an integrative and comparative view of the relationship between the two.

### East Asian Studies\(^{(1)}\)
Seventeen elective subjects (should follow the general structure of the East Asian Studies Minor program), a pre-thesis tutorial, and a thesis.

### Latin American Studies\(^{(2)}\)
Introduction to Latin American Studies (21F.084J/21S.202J) plus six elective subjects (including study in at least two disciplines and some work in Spanish or Portuguese language), a pre-thesis tutorial and a thesis.

### Psychology\(^{(3)}\)
Nine elective subjects including 9.00 and approved by a faculty member in the field.

### Russian Studies\(^{(2)}\)
Seven elective subjects (including Russian IV), a pre-thesis tutorial, and a thesis.

### Science, Technology, and Society (STS)
Eight subjects (including an STS HASS-D subject, STS.091, and STS.092), a pre-thesis tutorial, and a thesis.

### Theater Arts\(^{(3)}\)
Eight subjects (including Script Analysis, Theater Practicum, and Stagecraft), a pre-thesis tutorial, and a thesis.

### Women’s Studies\(^{(3)}\)
Seven subjects (including SP.401 Introduction to Women’s and Gender Studies), a pre-thesis tutorial, and a thesis. Students may submit a request to the Women’s Studies director to substitute two classes in lieu of the thesis and pre-thesis.

---

### And for the engineering/science component, one of the following:

**For 21E**
- Six elective subjects restricted to one of the engineering curricula and approved by a faculty member in the field.\(^{(1)}\)

**For 21S**
- Six elective subjects restricted to one of the science curricula and approved by a faculty member in the field.\(^{(1)}\)

---

### Departmental Program Units That also Satisfy the GIRs

<table>
<thead>
<tr>
<th>Unrestricted Electives</th>
<th>54–103</th>
</tr>
</thead>
</table>

---

### Total Units Beyond the GIRs Required for SB Degree

<table>
<thead>
<tr>
<th>180</th>
</tr>
</thead>
</table>

---

### Notes

\(^{(1)}\) As a matter of general Course 21 policy, subjects used to meet the General Institute Science Requirement, the REST Requirement, and the Laboratory Requirement may not be included in the six-subject Engineering or Science component of 21E or 21S degrees. Only one subject being used to meet the distribution element of the Humanities, Arts, and Social Sciences Requirement may be counted toward the humanities component of these degree programs.

\(^{(2)}\) American Studies, Ancient and Medieval Studies, East Asian Studies, Latin American Studies, Psychology, Russian Studies, Theater Arts, and Women’s Studies are also available as full majors by special arrangement with the Dean of the School of Humanities, Arts, and Social Sciences.

\(^{(3)}\) When possible, the subject satisfying the Institute Laboratory Requirement and one of the subjects satisfying the REST Requirement should be selected from this same curriculum, in addition to the regular requirement.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
As its name suggests, the Department of Linguistics and Philosophy houses a linguistics section and a philosophy section. Though they share a number of intellectual interests and a joint undergraduate major, these two sections are administratively autonomous with separate chairpersons, faculties, admissions procedures, curricular and degree requirements, and financial aid programs.

**UNDERGRADUATE STUDY**

**Bachelor of Science in Philosophy/ Course 24-1**

This major is designed to provide familiarity with the history and current status of the main problems in epistemology, metaphysics, and ethics; mastery of some of the technical skills requisite for advanced work in philosophy; facility at independent philosophical study; and work at an advanced level in an allied field. A relatively large amount of unrestricted elective time is available so that students can devise programs suited to individual needs and interests.

**Bachelor of Science in Linguistics and Philosophy/Course 24-2**

This major, also known as the Program in Language and Mind, aims to provide students with a working knowledge of a variety of issues that currently occupy the intersection of philosophy, linguistics, and cognitive science. Central among these topics are the nature of language, of those mental representations that we call “knowledge” and “belief,” and of the innate basis for the acquisition of certain types of knowledge (especially linguistic knowledge). Students have the option of pursuing either a philosophy track or a linguistics track. Both require a core set of four subjects drawn from both fields and are designed to teach students the central facts and issues in the study of language and the representation of knowledge. Each track requires, in addition, a set of four subjects drawn primarily from its discipline and is designed to prepare students for graduate study either in philosophy/cognitive science or in linguistics. A coherent program of three restricted electives (drawn from one or two of the following three areas: philosophy, linguistics, and brain and cognitive sciences) rounds out the major.

Note that students are prohibited from majoring in both 24-1 and 24-2.

**Minor Program**

The goal of the Minor Program in Philosophy is to introduce students to the methods of analytic philosophy and then to have them study a broad range of philosophers and philosophical issues at a more sophisticated level, culminating in an advanced seminar.

The minor consists of six subjects arranged into three levels of study as follows:

<table>
<thead>
<tr>
<th>Tier I</th>
<th>Two subjects:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>any HASS-D philosophy subject and</td>
</tr>
<tr>
<td></td>
<td>a logic course (24.241 Logic I, 24.242 Logic II, 24.243 Set Theory, or 24.244 Modal Logic, or a logic course in another department, e.g., Mathematics, if approved by the minor advisor)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tier II</th>
<th>Three non-introductory philosophy subjects, approved by the minor advisor</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Tier III</th>
<th>One subject:</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.260</td>
<td>Topics in Philosophy</td>
</tr>
</tbody>
</table>

The Minor Program in Linguistics consists of six subjects arranged in three levels of study, intended to provide students with breadth in the field of theoretical linguistics as a whole. The three levels are as follows:

<table>
<thead>
<tr>
<th>Tier I</th>
<th>One subject:</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.900</td>
<td>Introduction to Linguistics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tier II</th>
<th>At least three of the following, which must include 24.901, 24.902, and 24.903:</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.901</td>
<td>Language and Its Structure I: Phonology</td>
</tr>
<tr>
<td>24.902</td>
<td>Language and Its Structure II: Syntax</td>
</tr>
<tr>
<td>24.903</td>
<td>Language and Its Structure III: Semantics and Pragmatics</td>
</tr>
<tr>
<td>24.904</td>
<td>Language Acquisition</td>
</tr>
<tr>
<td>24.905</td>
<td>Psycholinguistics</td>
</tr>
<tr>
<td>24.957</td>
<td>Introduction to Linguistic Theory at an Advanced Level</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tier III</th>
<th>At least one term of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.910</td>
<td>Topics in Linguistic Theory (can be repeated for credit)</td>
</tr>
</tbody>
</table>

**GRADUATE STUDY**

**Master of Science in Linguistics**

The Department of Linguistics and Philosophy has an Indigenous Language Initiative program leading to a Master of Science in Linguistics. For more information about this experimental degree, please visit the website at [http://web.mit.edu/linguistics/www/mitili/](http://web.mit.edu/linguistics/www/mitili/) or contact the program administrator, mitili@mit.edu.

**Doctor of Philosophy in Linguistics**

The Linguistics Section offers a demanding program leading to the degree of Doctor of Philosophy in Linguistics. The normal course of study is four or five years, including the writing of the dissertation. The orientation of the program is highly theoretical, its central aim being the development of a general theory that reveals the rules and laws that govern the structure of a given language and the general laws and principles that govern all natural languages. The topics that form the core of this program are the traditional ones of phonology, morphology, syntax, semantics, and historical linguistics; but the program’s interests also extend into questions of the interrelations between linguistics and other disciplines such as philosophy and logic, literary studies, mathematics and the study of formal languages, acoustics, artificial intelligence, and computer science.

Approximately eight students enter the program each year in a highly selective admissions process. The department does not require that applicants have taken any particular set of subjects or that they be trained in any particular discipline. Instead, applicants must present evidence that they are able to engage in serious study of complex subject matter. Examples of such evidence might be mastery in depth of a language or group of languages, e.g., classical Greek, Semitic, Japanese; or work, academic or nonacademic, of high quality in a relevant area, especially if it requires considerable application, imagination, or ingenuity.

All students in the linguistics program must complete a set of required subjects unless they...
have acquired adequate preparation elsewhere. A program of studies in a minor field is also required in order to broaden the student’s educational experience. Before degree candidates begin their doctoral research, they are required to pass a comprehensive general examination, in conformity with Institute requirements. Students must also demonstrate competence in one foreign language.

The following subjects are normally required of all doctoral candidates in linguistics, unless they have obtained adequate preparation elsewhere:

24.942 Topics in the Grammar of a Less Familiar Language
24.949J Language Acquisition I
24.951 Introduction to Syntax
24.952 Advanced Syntax
24.957 Introduction to Linguistic Theory at an Advanced Level
24.958 Linguistic Structure
24.959 Workshop in Syntax and Semantics
24.961 Introduction to Phonology
24.962 Advanced Phonology
24.969 Workshop in Phonology and Morphology
24.970 Introduction to Semantics
24.973 Advanced Semantics
24.992 Survey of General Linguistics and one of the following:
24.956 Topics in Syntax
24.964 Topics in Phonology
24.979 Topics in Semantics

Before students begin their doctoral research, they are required to pass a comprehensive general examination that is composed of two parts. The first part is a written examination consisting of two substantial papers on topics chosen in consultation with members of the faculty. The two papers must present research on two distinct topics in two distinct subdisciplines of linguistics. The subdisciplines include phonetics, phonology, syntax, semantics, pragmatics, language acquisition, language processing, or any other area of linguistics, so long as there is a substantial theoretical-linguistic component to the papers. In conformity with Institute regulations, the second part of the examination is oral. It deals with topics treated in the candidate’s written examination, but is not

### Bachelor of Science in Philosophy/Course 24-1

<table>
<thead>
<tr>
<th>General Institute Requirements (GiRs)</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement [three subjects can be satisfied by subjects in the Departmental Program (for the field of concentration)]</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td>17</td>
</tr>
</tbody>
</table>

#### Communication Requirement
The program includes a Communication Requirement of 4 subjects:
- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

<table>
<thead>
<tr>
<th>PLUS Departmental Program</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject names below are followed by credit units and by prerequisites, if any. All subjects at the 200 level other than 24.222, 24.241 and 24.260 have as a prerequisite one previous philosophy subject.</td>
<td>72</td>
</tr>
</tbody>
</table>

#### Required Subjects(1)

- One HASS-D philosophy subject(2)

One History of Philosophy subject:
- 24.01 Classics in Western Philosophy, 12, HASS-D, CI-H
- 24.202 Topics in the History of Philosophy, 12, HASS, CI-M

One Knowledge and Reality subject:
- 24.09 Minds and Machines, 12, HASS-D, CI-H
- 24.101 Thinking about Life: Philosophical Problems in Evolution and Development, 12, HASS-D
- 24.111 Philosophy of Quantum Mechanics, 12, HASS
- 24.211 Theory of Knowledge, 12, HASS
- 24.215 Topics in the Philosophy of Science, 12, HASS
- 24.221 Metaphysics, 12, HASS

- 24.251 Introduction to Philosophy of Language, 12, HASS
- 24.253 Philosophy of Mathematics, 12, HASS
- 24.280 Foundations of Probability, 12, HASS

One Value subject:
- 24.02 Moral Problems and the Good Life, 12, HASS-D, CI-H
- 24.04 Justice, 12, HASS-D, CI-H
- 24.061 Bioethics, 12, HASS-D, CI-H
- 24.120 Moral Psychology, 12, HASS, CI-M
- 24.209 Philosophy in Film and Other Media, 12, HASS
- 24.213 Philosophy of Film, 12, HASS
- 24.222 Decisions, Games and Rational Choice, 12, HASS
- 24.231 Ethics, 12, HASS, CI-M
- 24.233J Philosophy of Law, 12, HASS
- 24.237 Feminist Theory, 12, HASS, CI-M
- 24.261 Philosophy of Love in the Western World, 12, HASS
- 24.262 Feeling and Imagination in Art, Science and Technology, 12, HASS
- 24.263 The Nature of Creativity, 12, HASS
- 24.264 Film as Visual and Literary Mythmaking, 12, HASS

One Logic subject:
- 24.118 Paradox and Infinity, 12, HASS
- 24.241 Logic I, 12, HASS
- 24.242 Logic II, 12, HASS
- 24.243 Classical Set Theory, 12, HASS
- 24.244 Modal Logic, 12, HASS

and

- 24.260 Topics in Philosophy(3), 12, HASS, CI-M

#### Restricted Electives
A coherent program of five additional subjects, of which two must be in philosophy. To satisfy the requirement that students take two CI-M subjects, students must take one of: 24.120, 24.201, 24.231 or 24.237, and 24.260.
limited to these and probes into the candidate’s competence in linguistics in general. Every candidate for the doctorate must complete a program of studies in a minor field, the purpose of which is to broaden the interests and capacities of the student in areas other than those of his or her major intellectual objective.

Doctor of Philosophy in Philosophy
The program of studies leading to the doctorate in philosophy provides subjects and seminars in such traditional areas as logic, ethics, metaphysics, epistemology, philosophy of science, philosophy of language, philosophy of mind, aesthetics, social and political philosophy, and history of philosophy. Interest in philosophical problems arising from other disciplines, such as linguistics, psychology, mathematics, and physics, is also encouraged.

To enter the doctoral program, students must have done well in their previous academic work and must be formally accepted as candidates for the degree by the Department of Linguistics and Philosophy. Although there are no formal course requirements for admission, applicants must satisfy the committee on admissions that their preparation in philosophy and allied disciplines is sufficient for undertaking the study of philosophy at the graduate level.

Before beginning dissertation research, students are required to take two years of coursework, including a proseminar in contemporary philosophy that all students must complete in their first year of graduate study. Students are also required to demonstrate competence in the following areas: value theory, logic, and the history of philosophy.

Interdisciplinary study is encouraged, and candidates for the doctorate may take a minor in a field other than philosophy. Options for minors include psychology, linguistics, and logic. Students who elect one of these options are expected to complete three approved graduate subjects in their minor field. There is no general language requirement for the doctorate, except in those cases in which competence in one or more foreign languages is needed to carry on research for the dissertation.

Inquiries
Information regarding undergraduate or graduate academic programs, research activities, admissions, financial aid, and assistantships may be obtained from the Department of Linguistics and Philosophy, Room 32-D808, MIT, 617-253-9372.

FACULTY AND STAFF
Faculty and Teaching Staff
Stephen Yablo, PhD
Professor of Philosophy
Head of Department

Professors
Alexander Byrne, PhD
Professor of Philosophy
(On leave, fall)
Noam Chomsky, PhD
Professor of Linguistics
Suzanne Flynn, PhD
Professor of Second Language Acquisition

Sally Haslanger, PhD
Professor of Philosophy
Irene R. Heim, PhD
Professor of Linguistics
Richard Holton, PhD
Professor of Philosophy
Sabine Iatridou, PhD
Professor of Linguistics
Michael Kenstowicz, PhD
Professor of Linguistics
Rae Langton, PhD
Professor of Philosophy
Alec Marantz, PhD
Kenan Sahin Distinguished Professor of Linguistics
(On leave)
Vann McGee, PhD
Professor of Philosophy
Shigeru Miyagawa, PhD
Kochi Prefecture-John Manjiro Professor of Japanese Language and Culture
Professor of Linguistics
Wayne O’Neil, PhD
Professor of Linguistics
David Pesetsky, PhD
Ferrari P. Ward Professor of Linguistics
Cecil H. Green (1923) MacVicar Faculty Fellow
(On leave, spring)
Irving Singer, PhD
Professor of Philosophy
Robert Stalnaker, PhD
Laurance S. Rockefeller Professor of Philosophy
Donca Steriade, PhD
Professor of Linguistics
Kenneth N. Wexler, PhD
Professor of Psychology and Linguistics

Associate Professors
Michel DeGraff, PhD
Associate Professor of Linguistics
Kai von Fintel, PhD
Associate Professor of Linguistics
Daniel Fox
Associate Professor of Linguistics

Notes
(36) No more than four of the total number of philosophy subjects for the major may be HASS-D philosophy subjects. At least three of the total number of philosophy courses must be at the 200 level or above.
(37) May not also satisfy the departmental distribution requirement in philosophy.
(38) Prerequisite: two subjects in philosophy.
For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
Bachelor of Science in Linguistics and Philosophy/Course 24-2

General Institute Requirements (GIRs)  
Subjects  
Science Requirement  6  
Humanities, Arts, and Social Sciences Requirement [three subjects can be satisfied by subjects in the Departmental Program (for the field of concentration)]  8  
Restricted Electives in Science and Technology (REST) Requirement  2  
Laboratory Requirement  1  
Total GIR Subjects Required for SB Degree  17

Communication Requirement  
The program includes a Communication Requirement of 4 subjects:  
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and  
2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program  
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects for Both Tracks  48  
24.09 Minds and Machines, 12, HASS-D, CI-H  
24.20 Logic I, 12, HASS  
24.251 Introduction to Philosophy of Language, 12, HASS  
24.900 Introduction to Linguistics, 12, HASS-D, CI-H  
Students choose either a linguistics or philosophy track

Required Subjects for Linguistics Track  48  
24.901 Language and Its Structure I: Phonology, 12, HASS; 24.900  
24.902 Language and Its Structure II: Syntax, 12, HASS, CI-M; 24.900  
24.903 Language and Its Structure III: Semantics and Pragmatics, 12, HASS; 24.900  
24.910 Topics in Linguistic Theory, 12, HASS; CI-M

Required Subjects for Philosophy Track  48  
24.201 Topics in the History of Philosophy, 12, HASS, CI-M  
24.206 Topics in Philosophy, 12, HASS, CI-M  
One of the following Knowledge and Reality subjects:  
24.10 Thinking about Life: Philosophical Problems in Evolution and Development, 12, HASS-D  
24.111 Philosophy of Quantum Mechanics, 12, HASS  
24.211 Theory of Knowledge, 12, HASS  
24.215 Topics in the Philosophy of Science, 12, HASS  
24.221 Metaphysics, 12, HASS  
24.253 Philosophy of Mathematics, 12, HASS  
24.280 Foundations of Probability, 12, HASS  
One of the following three subjects:  
9.65 Cognitive Processes, 12, HASS; 9.00  
24.904 Language Acquisition, 12, HASS; 24.900*  
24.905 Psycholinguistics, 12, HASS; 24.900*

Restricted Electives for Both Tracks  27–36  
A coherent program of three additional subjects from one or two of the following three areas: brain and cognitive sciences, linguistics, and philosophy.

Departmental Program Units That also Satisfy the GIRs  (36)

Unrestricted Electives  84–93

Total Units Beyond the GIRs Required for SB Degree  180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student's departmental program will count toward one or the other, but not both.

Notes  
*Alternate prerequisites are listed in the subject description.  
For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
The Literature faculty’s mission is to maintain a level of excellence and innovation consistent with the best universities while remaining responsive to MIT’s distinctive intellectual environment. The curriculum emphasizes interdisciplinary approaches to literary texts as well as theoretical, generic, and thematic subjects that range across geographical and historical boundaries.

The Literature Section accommodates students with a wide variety of interests and diverse career choices. The major provides a solid grounding in the discipline while remaining flexible enough to allow students to explore the particular domains that most interest them. Students graduating from the MIT Literature program have in recent years been admitted into the best doctoral programs in the country and abroad. For those not pursuing literature as a career, the program nonetheless develops transferrable skills in writing, comprehension, and analysis relevant to a variety of different professional paths—both to traditional choices (e.g., journalism, law, and medical school) and to more esoteric ones, such as working in the gourmet food industry or computer game design.

Depending on the depth of one’s engagement, a student may major, minor, or concentrate in literature. Regardless of the individual choice, our courses will introduce you to the pleasures of reading and interpretation, expose you to different ways of thinking about the world, and lead to a competence in writing and communication that will remain with you the rest of your life.

A supplement to this catalogue, available online and from Literature Headquarters, Room 14N-407, offers detailed descriptions of all literature subjects and includes specific information about required texts, writing assignments, and exams.

The Literature curriculum is arranged in four graduated categories:

- **Introductory subjects** (21L.000–21L.017) focus on major literary texts grouped in broad historical and generic sequences; all introductory subjects carry HASS-Distribution credit, and most carry Communication Intensive credit.

- **Samplings** (21L.310–21L.325) are 6-unit subjects that provide both an alternative route into literary study and a less intensive means for students to sustain a commitment to reading and textual interpretation. Their focus is on critical exploration, textual comprehension, and group discussion, with less sustained attention to analytic writing skills. Students can combine two 6-unit Sampling subjects to count as a single 12-unit HASS Elective, equivalent to a subject in the Intermediate tier. No more than four Sampling subjects may be combined in this manner.

- **Intermediate subjects** (21L.420–21L.512) explore literary forms in greater depth and center on historical periods, literary themes, or genres.

- **Advanced subjects** (Seminars 21L.701–21L.715)—usually restricted to students who have taken at least two previous subjects in literature—encourage a greater degree of independent work, such as oral reports and other special projects. Enrollment in seminars is strictly limited to a maximum of 12 students.

Concentrations in literature are available in particular genres (e.g., poetry, drama, fiction) and in historical periods (e.g., ancient studies, 19th-century literature, modern and contemporary literature), as well as in popular culture, media and film studies, minority and ethnic studies, literary theory, and a range of national literatures.

** Bachelor of Science in Literature/Course 21L**

The program in Literature leading to the degree of Bachelor of Science in Literature is equivalent to the curricula in English (or literary studies) of the major liberal arts universities. The Literature curriculum is notable also for its inclusion, along with traditional literary themes and texts, of materials drawn from film and media, from popular culture, and from minority and ethnic cultures.

 Majors are required to take a minimum of 10 subjects, three of which must be seminars and no more than three of which may be introductory subjects. Students develop an appropriate course of study in consultation with a faculty advisor; majors choose from one of two areas in organizing four of their restricted electives (three for joint majors): historical periods or thematic complexes.

**Minor Program in Literature**

The minor program aims to lay a foundation for advanced study and to enhance a student’s appreciation of major narrative, poetic, and dramatic texts in relation to the cultures that produced them.

The Minor Program in Literature consists of six subjects arranged into three levels of study as follows:

- **Tier I** At least one and no more than two subjects from 21L.000–21L.017 (Introductory Level)
- **Tier II** Two or three subjects from 21L.420–21L.512 (Intermediate Level)
- **Tier III** At least two subjects from the Literature Seminar listings, 21L.701–21L.715 (Advanced Level)

At least two subjects must focus primarily on material from before 1900.

**Joint Degree Programs**

Joint degree programs are offered in literature in combination with a field in engineering or science (21E, 21S). See the joint major programs listed under Humanities.

Subjects in literature are numbered 21L.001 through 21L.999 in Part 3. Further information on subjects and programs may be obtained from Literature Headquarters, Room 14N-407, 617-253-3581, lit@mit.edu.

**Faculty and Staff**

**Faculty and Teaching Staff**

James Buzard, PhD
Professor of Literature
Section Head

**Professors**

Peter S. Donaldson, PhD
Professor of Literature
(On leave, fall)

Diana Henderson, PhD
Professor of Literature
Bachelor of Science in Literature/Course 21L

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

**Communication Requirement**
The program includes a Communication Requirement of 4 subjects:
- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

**PLUS Departmental Program**
Subject names below are followed by credit units, and by prerequisites if any

**Required Subjects**
Three seminar level subjects
To satisfy the requirement that students complete two Communication Intensive subjects in the major, students must take two subjects from this list of approved CI-M subjects for Course 21L: 21L.473, 21L.701, 21L.702, 21L.703, 21L.704, 21L.705, 21L.706, 21L.707, 21L.708, 21L.709.

Note: Four of the ten subjects required to satisfy the major (three of the eight for joint majors) must be chosen, in consultation with a faculty advisor, either from four of five historical periods (ancient/medieval; Renaissance; Restoration and 18th century; 19th century; 20th century and contemporary) or from four of five thematic complexes (historical period; genre; author study; film, media, and popular culture; gender studies, ethnic studies, and theory).

**Restricted Electives**
A coherent program of seven additional subjects from the literature curriculum (see above).

**Departmental Program Units That also Satisfy the GIRs**
(27–36)

**Unrestricted Electives**
87–117

**Total Units Beyond the GIRs Required for SB Degree**
180
No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

John Hildebidle, PhD
Professor of Literature

Henry Jenkins III, PhD
Professor of Humanities

John E. Burchard
Professor of Humanities Studies and Literature

Codirector, Comparative Media Studies Program

Alvin Charles Kibel, PhD
Professor of Literature

Ruth Perry, PhD
Professor of Literature and Womens’ Studies

MacVicar Faculty Fellow (On leave)

Stephen James Tapscott, PhD
Professor of Literature

David Thorburn, PhD
Professor of Literature

MacVicar Faculty Fellow (On leave, spring)

William Uricchio, PhD
Professor of Comparative Media Studies

Codirector, Comparative Media Studies Program (On leave, spring)

**Associate Professors**
James D. Cain, PhD
Associate Professor of Literature

Mary C. Fuller, PhD
Associate Professor of Literature

Noel B. Jackson, PhD
Homer A. Burnell Career Development Associate Professor of Literature (On leave, fall)

Shankar Raman, PhD
Associate Professor of Literature

**Assistant Professors**
Sandy Alexandre, PhD
Assistant Professor of Literature

Alisa Braithwaite, PhD
Assistant Professor of Literature

Sarah Brouillette, PhD
Assistant Professor of Literature

**Senior Lecturer**
Wyn Kelley, PhD

**Lecturers**
Howard Eiland, PhD

Ina Lipkowitz, PhD

**Professors Emeriti**
Albert Ramsdell Gurney, Jr., MFA
Professor of Literature, Emeritus

Louis Kampf, BA
Professor of English, Emeritus

Irene Tayler, PhD
Professor of Literature, Emerita
The Music Program offers a broad range of opportunities to experience and explore the field of music. A great variety of subjects is offered, ranging from Fundamentals of Music to Senior Seminar for Music Majors. The subjects are arranged into six categories: introductory, history/literature, theory/composition, performance, special topics/advanced subjects, and music/media. Most students begin with introductory subjects, but anyone with musical training is encouraged to begin with history/literature or theory/composition subjects, which constitute the nucleus of the program. Graduate credit is available for some performance and special topics/advanced subjects.

The symphony orchestra, choral groups, wind and jazz ensembles, chamber music groups, and gamelan and rambax ensembles are an integral part of MIT’s cultural life and of any student’s musical development, no matter what technical proficiency they possess. Academic credit is available for some performance activities and instrumental study. Auditions are held at the beginning of each term.

The Music faculty is comprised of professional composers, performers, historians, and theorists, whose individual interests in the confluence of history, theory, and performance are essential to our integrated music program.

**Bachelor of Science in Music**

The undergraduate program leading to the degree of Bachelor of Science in Music is designed to provide a thorough grounding in the history and counterpoint of Western music; in-depth studies in the history and repertoires of Western and World music; and performing experience in small and/or large ensembles. Five required subjects, two terms of performance subjects, three restricted electives, and twelve additional units (chosen in consultation with the major’s advisor) form the core of the program, which can be supplemented by eight unrestricted electives. This program is very similar to that of a music major at leading liberal arts colleges and universities in that it prepares a student for graduate work in music. Students who declare music as their major must have demonstrated proficiency in instrumental or vocal performance and in harmony and counterpoint, ordinarily by participating in a performance subject and by obtaining a grade of B or better in 21M.301, respectively.

Qualified performers may substitute three full years of 21M.480 and a senior recital for the two performance subjects and two of the four electives.

**Minor Program in Music**

The Minor Program in Music consists of six subjects and is designed to give students exposure to three main branches of musical activity: performance, music literature, and music writing. Four subjects are at the introductory or intermediate level; the remaining two provide depth in one of the three branches.

**Tier I** One subject from the following:
- 21M.011 Introduction to Western Music
- 21M.020 Introduction to World Music
- 21M.051 Fundamentals of Music

Students with prior musical knowledge or experience may wish to substitute a subject from Tier II or III for the subject in Tier I. Please consult the minor advisor.

**Tier II** Three subjects, one from each of the following areas:
- History/Literature: 21M.026, 21M.201–299
- Theory/Composition: 21M.301
- Performance (two terms): 21M.401–499

**Tier III** Two subjects from one of the following areas of specialization:
- History/Literature: 21M.201–299, 21M.500
- Theory/Composition: 21M.302–399
- Performance (four terms): 21M.401–499

**Joint Degree Programs**

For students interested in combining the study of engineering or science with humanities, joint majors in the 21S or 21E degree programs provide the opportunity to pursue special interests. The joint major requires four subjects, two terms of performance subjects, two restricted electives, and twelve additional units in music, plus six elective subjects in an engineering or science curriculum. Joint majors may also substitute three full years of 21M.480 and a senior recital for the two performance subjects and two of the three electives.

**Theater Arts**

The Program in Theater Arts offers the opportunity for an imaginative and rigorous engagement with the arts and disciplines of theater: acting, directing, playwriting, design, technical work, dance, and scholarship. The program combines work in the classroom, in the studio, and on the stage. Performance is the testing ground for what is learned in the classroom and the experiences, from student-generated workshops to fully-mounted productions by Dramashop and Playwrights-in-Performance. All these activities are guided by a professional faculty and staff, often with the enriching participation of guest artists.

The Minor in Theater Arts is designed to give students the opportunity to experiment imaginatively but constructively in the making of theater. The flexibility of the minor allows students either to explore the basic principles of several theater disciplines or to concentrate more deeply on one.

**Minor Program in Theater Arts**

The Minor Program in Theater Arts consists of the equivalent of six subjects arranged in three levels of study as follows:

**Tier I** One subject from the following:
- 21M.274 Shakespeare at the Opera
- 21M.621 Theater and Cultural Diversity in the US
- 21M.710 Script Analysis
- 21M.711 Production Seminar
- 21M.712 African-American Performance
- 21M.713 Selected Studies in Theater

**Tier II** Four subjects:
- 21M.600 Introduction to Acting
- 21M.603 Principles of Design
### Bachelor of Science in Music/Course 21M

**General Institute Requirements (GIRs)**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement (three subjects can be satisfied by subjects in the Departmental Program)</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total GIR Subjects Required for SB Degree**

17

**Communication Requirement**
The program includes a Communication Requirement of 4 subjects:
- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

**PLUS Departmental Program**

Subject names below are followed by credit units, and by prerequisites if any

**Required Subjects**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>21M.220 Early Music, 12, HASS, CI-M; 21M.201*</td>
<td>72</td>
</tr>
<tr>
<td>21M.301 Harmony and Counterpoint I, 12, HASS-D; 21M.053*</td>
<td></td>
</tr>
<tr>
<td>21M.303 Harmony and Counterpoint II, 12, HASS; 21M.301</td>
<td></td>
</tr>
<tr>
<td>21M.303 Writing in Tonal Forms I, 12, HASS; 21M.302</td>
<td></td>
</tr>
<tr>
<td>Two terms of 6-unit Performance subjects</td>
<td></td>
</tr>
<tr>
<td>21M.500 Senior Seminar in Music, 12*, HASS, CI-M</td>
<td></td>
</tr>
</tbody>
</table>

**Restricted Electives**

48

One subject in theory/composition (21M.300–21M.399), one subject in Western music (21M.230–21M.289), one subject in World music (21M.291–21M.299), and one further 12-unit subject, which may be in theory/composition, history/literature, or performance (two 6-unit terms of 21M.401–21M.499), to be selected in consultation with the major advisor.

Qualifying students may, with faculty approval, substitute three full years of **21M.480** and a senior recital for the required performance subjects and 24 additional units.

**Departmental Program Units That also Satisfy the GIRs**

(36)

**Unrestricted Electives**

96

**Total Units Beyond the GIRs Required for SB Degree**

180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

**Notes**

* Prerequisites are listed in the subject description.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

### Bachelor of Science in Music/Course 21M

- 21M.604 Playwriting I
- 21M.605 Voice and Speech for the Actor
- 21M.606 Introduction to Stagecraft
- 21M.611 Foundations of Theater Practice
- 21M.645 Composition for Stage and Performance
- 21M.670 Traditions in American Concert Dance: Gender and Autobiography
- 21M.675 Dance Theory and Composition
- 21M.704 Musical Theater Workshop
- 21M.705 The Actor and the Text
- 21M.707 Theater and Collective Creation
- 21M.714 Selected Topics in Theater Arts (minimum of 9 units)
- 21M.732 Costume Design for the Theater
- 21M.733 Design for the Theater: Scenery
- 21M.734 Lighting Design for the Theater
- 21M.735 Technical Design: Scenery, Mechanisms, Special Effects
- 21M.775 Hip-Hop
- 21M.785 Playwrights’ Workshop
- 21M.790 The Director’s Craft
- 21M.830 Acting: Techniques and Style
- 21M.840 Performance Media
- 21M.846 Topics in Performance Studies

** Tier III**

- 21M.820 Technical Theater Special Topics (minimum of 6 units) and either
- 21M.820 Technical Theater Special Topics (minimum of 6 units) and either
- 21M.805 Theater Practicum or six units from the following subjects:
- 21M.851 Special Topics in Drama
- 21M.863 Advanced Topics in Theater Arts
- 21M.873 IAP Theater Arts Topics

Subjects in theater arts are numbered 21M.600 to 21M.899 in Part 3. For further information on subjects and programs, contact the Music and Theater Arts Office, Room 4-246, 617-253-3210.


**FACULTY AND STAFF**

**Faculty and Teaching Staff**

Janet Sonenberg, MFA  
Professor of Theater Arts  
MacVicar Faculty Fellow  
Section Head

**Professors**

Alan Brody, PhD  
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(On leave)

Peter Child, PhD  
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MacVicar Faculty Fellow

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Institute Professor  
Professor of Music

Ellen T. Harris, PhD  
Professor of Music  
Class of 1949 Professor of Music

Lowell Edwin Lindgren, PhD  
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MacVicar Faculty Fellow

Marcus Aurelius Thompson, DMA  
Robert R. Taylor Professor  
Professor of Music  
MacVicar Faculty Fellow

Barry Lloyd Vercoe, DMA  
Professor of Media Arts and Sciences

Evan Ziporyn, PhD  
Kenan Sahin Distinguished Professor of Music  
(On leave)

**Associate Professors**

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Class of 1948 Professor of Theater

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(On leave)

**Assistant Professors**

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Jay Scheib, MFA  
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David Deveau, MM  
Senior Lecturer in Music

Martin Marks, PhD  
Senior Lecturer in Music

Michael Ouellette, MFA  
Senior Lecturer in Theater Arts

George Ruckert, PhD  
Senior Lecturer in Music

Pamela Sharon Wood, MM  
Senior Lecturer in Music

**Lecturers**

William C. Cutter, DMA  
Director, Choral Programs

Frederick Harris, PhD  
Director, Wind Ensembles

Mark Harvey, PhD  
Lecturer in Music

Kim Mancuso, MFA  
Lecturer in Theater Arts

Jean Rife, BM  
Lecturer in Music

Elena L. Ruehr, PhD  
Lecturer in Music

Charles Shadle, PhD  
Lecturer in Music

**Instructors**

William A. Fregosi, MFA  
Technical Instructor in Theater Arts

Leslie Cocuzzo Held, BA  
Technical Instructor in Theater Arts

Michael Katz, MFA  
Technical Instructor in Theater Arts

**Professors Emeriti**

Jeanne Shapiro Bamberger, MA  
Professor of Music, Emerita

Stephen Erdely  
Professor of Music, Emeritus
Political science is concerned with the systematic study of government and the political process. Within the discipline, scholars analyze the development, distribution, and uses of political power; determinants and consequences of various forms of political behavior and sources of political conflict; ways in which conflicts are both intensified and resolved; and the relationship between the individual and the state.

Political science is a discipline of special interest to scientists and engineers who must understand the political system within which they live in order to evaluate their influence upon that system. It is of interest as well to those students who are considering careers in public service or university teaching and research.

The Department of Political Science has a research-oriented faculty that welcomes both undergraduate and graduate students in ongoing research. The department covers the fields of American politics and public policy, comparative politics, international relations and foreign policy, and political philosophy and social theory, with particular emphasis on ethnicity and identity, international security, representation, and the politics of globalization.

UNDERGRADUATE STUDY

Bachelor of Science in Political Science/Course 17

The political science curriculum for undergraduates combines professional social science training with opportunities for a broad liberal arts education. Students may choose subjects from a wide range of both undergraduate and graduate offerings, and are encouraged to engage in independent research projects. In addition, the department sponsors an internship program in which students work in governmental agencies, legislative offices, community associations, international organizations, and advocacy groups at all levels.

The undergraduate program prepares students for study in political science, law, public policy, and related fields, and for careers in government, business, law, research, teaching, or journalism. This program is also designed to give students, whatever their career objectives, an understanding of political institutions and processes. Some students want to focus on political systems themselves; others choose to concentrate on the political aspects of public policy, focusing on such issues as the environment, health, or arms control. Both of these perspectives are found in the program.

Subjects are offered by the department in the following fields: political theory, American politics and public policy, security studies, comparative politics, and international relations and foreign policy. Students may work out individualized programs with the assistance of a faculty advisor.

In the junior year students are introduced to the major theoretical and methodological themes of political science in two subjects:

- 17.869 Political Science Scope and Methods (typically fall term, junior year) and
- 17.871 Political Science Laboratory (typically spring term, junior year)

The department believes that every political science major should have the experience of conducting and writing at least one substantial research project, a requirement that is fulfilled by the senior thesis. Each undergraduate chooses a thesis advisor and a second thesis reader in his or her area of interest. The student then registers for:

- 17.ThT Thesis Research Design Seminar (fall term, senior year) and
- 17.ThU Thesis (spring term, senior year)

In addition to the thesis, there are numerous other opportunities for students to pursue research interests. Students are eligible to receive academic credit or limited funding for expenses or wages through the Institute-wide Undergraduate Research Opportunities Program. Students should consult the department's UROP coordinator to discuss specific projects.

Minor Program in Political Science

The Minor Program in Political Science is designed to ensure that students acquire both depth and breadth of understanding in the discipline. A minor in political science consists of six subjects. The requirements for the minor parallel the requirements for the major and are structured as follows:

Tier I

- Two or three introductory political science subjects (designated with two-digit numbers in different areas): Political philosophy/social theory (17.00–17.09) American politics (17.20–17.29) Public policy (17.30–17.39, or designated as fulfilling the public policy requirement in the subject description) International politics (17.40–17.49, 17.50–17.59)

Tier II

- Two or three upper-level political science subjects (designated with three-digit numbers in one of the following areas of specialization): Political philosophy/social theory (17.000–17.099) American politics (17.200–17.299) Public policy (17.300–17.399, or designated as fulfilling the public policy requirement in the subject description) International politics (17.400–17.499, 17.500–17.599)

Tier III

- At least one subject from the following:
  - 17.869 Political Science Scope and Methods
  - 17.871 Political Science Laboratory

For a listing of available subjects in these areas, consult Tobie Weiner in the Political Science Undergraduate Office, Room E53-484 or the HASS Office, Room 14N-408.

Minor in Applied International Studies

MIT educates its students for a future in an increasingly global economy and international research environment. The interdisciplinary HASS Minor in Applied International Studies prepares undergraduates for this reality by integrating international learning into their course of study. The six-subject minor is organized into three areas that address key components of international education.

The first area is language and culture. Lasting economic and social relationships in an international context are only possible for those who speak the language of a foreign country and are familiar with its cultural dimensions. Therefore, this part of the minor gives students the
opportunity to become competent in a foreign language and learn about the culture of a foreign country or region.

The second area is international politics, economics, and history. This area offers students a set of subjects that help them to critically understand the economic, political, cultural and historical concepts and movements that create an increasingly interconnected world. Students take two or three subjects from this area. One of these subjects focuses on a chosen geographical region of specialization.

The third area is a significant international experience. Recognizing that theoretical learning should be combined with hands-on experience, the Minor in Applied International Studies includes a stay-abroad component that exposes students to the challenges and opportunities of working and living in another culture. Within this area, the minor offers students courses that directly prepare them for these experiences abroad and help them to reflect on their work, research, or study-abroad experience after the return on campus. Students choose one or two courses. The Minor in Applied International Studies requires a stay abroad for at least three months. Students elect their stay abroad options in close consultation with the minor advisor. The experience abroad will typically take place within an internship or a study abroad structure. Special research stays can be arranged.

**Tier I**

*Language and culture: two or three subjects that expose students to foreign languages and/or cultures, beyond first-year language subjects.*

At least two subjects must focus on one country or region. Consult the minor advisor for a list of approved subjects.

**Tier II**

*Politics, economics, and history: two or three subjects, one of which must focus on the geographical area chosen in Tier I. Consult the minor advisor for a list of approved subjects.*

---

### Bachelor of Science in Political Science/Course 17

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement [three subjects can be satisfied by subjects in the Departmental Program]</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication Requirement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The program includes a Communication Requirement of 4 subjects:</td>
<td></td>
</tr>
<tr>
<td>2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and</td>
<td></td>
</tr>
<tr>
<td>2 subjects designated as Communication Intensive in the Major (CI-M).</td>
<td></td>
</tr>
</tbody>
</table>

**PLUS Departmental Program**

<table>
<thead>
<tr>
<th>Required Subjects(i)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.869 Political Science Scope and Methods, 12, HASS, CI-M</td>
<td>51</td>
</tr>
<tr>
<td>17.871 Political Science Laboratory, 15, LAB; 17.869</td>
<td></td>
</tr>
<tr>
<td>17TH  Thesis Research Design Seminar, 12, CI-M; 17.869 or 17.871 (i)</td>
<td></td>
</tr>
<tr>
<td><strong>17TH Undergraduate Political Science Thesis</strong> (at least 12 units; additional units by special arrangement)</td>
<td></td>
</tr>
<tr>
<td><strong>Restricted Electives</strong></td>
<td>60–84</td>
</tr>
<tr>
<td>Normally seven subjects divided as follows:</td>
<td></td>
</tr>
<tr>
<td><strong>Political philosophy/social theory:</strong> One political science subject in the field of political philosophy/social theory (<strong>17.00–17.099</strong>)</td>
<td></td>
</tr>
<tr>
<td><strong>American politics:</strong> One political science subject in the field of American politics (<strong>17.20–17.299</strong>)</td>
<td></td>
</tr>
<tr>
<td><strong>Public policy:</strong> One political science subject in the field of public policy (<strong>17.30–17.399</strong>), or a subject in another field designated as fulfilling the public policy requirement</td>
<td></td>
</tr>
<tr>
<td><strong>International politics:</strong> One political science subject in the fields of International relations/security studies (<strong>17.40–17.499</strong>) or comparative politics (<strong>17.50–17.599</strong>)</td>
<td></td>
</tr>
<tr>
<td>Plus three additional political science subjects representing a coherent plan of study. Specific subjects satisfying these criteria should be chosen in consultation with a faculty advisor.</td>
<td></td>
</tr>
</tbody>
</table>

**Departmental Program Units That also Satisfy the GIRs**

<table>
<thead>
<tr>
<th>Unrestricted Electives</th>
<th>81–99</th>
</tr>
</thead>
</table>

**Total Units Beyond the GIRs Required for SB Degree**

180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

**Notes**

* Alternate prerequisites are listed in the subject description.
  \(i\) Students typically enroll in subjects as follows: **17.869**, fall term, junior year; **17.871**, spring term, junior year; **17TH**, fall term, senior year; **17TH**, spring term, senior year.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
PART

Graduate Study

The Department of Political Science offers programs leading to the Master of Science in Political Science and the Doctor of Philosophy.

Entrance Requirements for Graduate Study

All applicants must take the GRE general test. Non-native English speakers must take the TOEFL. Applicants from all disciplines are welcome. Applicants need not have majored in political science, though some prior course work in political science or related subjects, such as history, economics, philosophy, psychology, or sociology is helpful.

Master of Science in Political Science

The Master of Science in Political Science is a one-year program intended for students who wish to develop skills in applied research in preparation for a career in public policy or with a business or research organization. The master’s program emphasizes intensive preparation in a single field of study. Applicants to the SM program should specify their field of specialization.

The minimum number of subjects required for the SM degree is six graduate subjects, at least four of which must be completed in the Political Science Department at MIT. The remaining two may be taken elsewhere at MIT or through cross-registration at Harvard University. A 3.5 GPA must be maintained. A master’s thesis is required. See the section on Graduate Education in Part I for the general requirements for the SM.

Accelerated Master of Science in Political Science

The department offers a five-year program leading to the Bachelor of Science and Master of Science, awarded simultaneously. This program is open to MIT undergraduates only. It allows the student to plan for a single combined SB-SM thesis written during the last three terms at the Institute. Undergraduate Institute requirements may be completed during the fifth year of the program.

Doctor of Philosophy

Doctoral students must complete the following requirements (for specifics see the department handbook):

- A full-year seminar for first-year students covering the fields of political science
- One class in statistics
- One class in empirical research methods
- One class in political philosophy
- Reading proficiency in one language other than English (demonstrated by four semesters of course work or an exam) or knowledge of advanced statistics (demonstrated by three semesters of course work or an exam)
- A second-year paper
- A doctoral thesis

In addition, doctoral students are required to elect two of the following major fields: American politics and public policy; comparative politics; international relations; models and methods; political economy; political philosophy and social theory; and security studies.

The requirements in each of the two elected fields are as follows:

First major field: a written and oral general exam.
Second major field: three courses in the field, selected to ensure breadth and avoid significant overlap with the first field.

Specific fields may have additional requirements.

Students may take subjects in other MIT departments. Cross-registration arrangements also permit enrollment in subjects taught in the Graduate School of Arts and Sciences at Harvard University and in some of Harvard’s other graduate schools. Students are encouraged to do field research and develop close working ties with faculty members engaged in major research activities.

Teaching and Research Assistantships

Financial assistance is available to qualified applicants in the form of research and teaching assistantships and a limited number of fellowships. Research assistants work under faculty supervision on projects administered by the department and through MIT-affiliated research facilities such as the Center for International Studies (described in the section on Interdisciplinary Research and Study in Part I) and the Center for Technology, Policy, and Industrial Development, part of the Engineering Systems Division. In addition, advanced graduate students may qualify to become teaching assistants.

Inquiries

Additional information regarding graduate programs in the department and admissions may be obtained from the graduate administrator, Susan Twarog, 617-253-8336. Information on research programs, assistantships and financial aid, may be obtained from the administrative officer, Kenneth Goldsmith, 617-253-6635. Written inquiries should be addressed to Department of Political Science, MIT, Room E53-467, 77 Massachusetts Avenue, Cambridge, MA 02139-4307.
FACULTY AND STAFF

Faculty and Teaching Staff
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MacVicar Faculty Fellow
Head of Department

Professors
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Eliot E. Morison Professor of Political Science
Suzanne Berger, PhD
Raphael Dorman and Helen Starbuck Professor of Political Science
Nazli Choucri, PhD
Professor of Political Science
Joshua Cohen, PhD
Leon and Anne Goldberg Professor of Humanities
Professor of Philosophy and Political Science
(On leave)
Richard M. Locke, PhD
Alvin J. Siteman Professor of Entrepreneurship and Political Science
(On leave)
Stephen M. Meyer, PhD
Professor of Political Science
Michael Joseph Piore, PhD
David W. Skinner Professor of Political Economy and Political Science
Barry R. Posen, PhD
Ford International Professor of Political Science
Richard J. Samuels, PhD
Ford International Professor of Political Science, Director, Center for International Studies
James M. Snyder, Jr., PhD
Arthur and Ruth Sloan Professor of Political Science and Economics
Stephen W. Van Evera, PhD
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(On leave)

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Associate Professor of Political Science
Andrea Campbell, PhD
Associate Professor of Political Science
(On leave)
Melissa Nobles, PhD
Associate Professor of Political Science
Chappell H. Lawson, PhD
Associate Professor of Political Science
Kenneth A. Oye, PhD
Associate Professor of Political Science
Roger Petersen, PhD
Associate Professor of Political Science
Jonathan Rodden, PhD
Ford Career Development Associate Professor of Political Science
(On leave)
Edward Steinfeld, PhD
Associate Professor of Political Science

Assistant Professors
Taylor Flavel, PhD
Assistant Professor of Political Science
(On leave)
Orit Kedar, PhD
Assistant Professor of Political Science
(On leave)
Gabriel Lenz, PhD
Assistant Professor of Political Science
David Andrew Singer, PhD
Assistant Professor of Political Science
Sarah Song, PhD
Assistant Professor of Political Science
(On leave, fall)
Lily Tsai, PhD
Assistant Professor of Political Science

Professors Emeriti
Donald L. M. Blackmer, PhD
Professor of Political Science, Emeritus
Lincoln P. Bloomfield, PhD
Professor of Political Science, Emeritus
Willard R. Johnson, PhD
Professor of Political Science, Emeritus
William W. Kaufmann, PhD
Professor of Political Science, Emeritus
Lucian W. Pye, PhD, LLD
Professor of Political Science, Emeritus
George W. Rathjens, PhD
Professor of Political Science, Emeritus
Harvey M. Sapolsky, PhD
Professor of Political Science, Emeritus
Eugene B. Skolnikoff, PhD
Professor of Political Science, Emeritus
The Program in Science, Technology, and Society (STS) focuses on the ways in which scientific, technological, and social factors interact to shape modern life. The program brings together humanists, social scientists, engineers, and natural scientists, all committed to transcending the boundaries of their disciplines in a joint search for new insights and new ways of reaching science and engineering students. The goal of the program is to set up a forum to explore the relationship between what scientists and engineers do and the constraints, needs, and responses of society.

Located in a major university where most people study science and engineering, STS is dedicated to understanding the context of science and engineering.

UNDERGRADUATE STUDY

Engineering and science students are increasingly seeking to understand the social and historical contexts in which they will work and the social consequences of what they will do in their professional careers. STS subjects help them think realistically and creatively about the intellectual, moral, political, and social issues raised by the rapid growth of science and technology in the 20th century and beyond.

STS contributes to undergraduate education at MIT in several ways. It offers general subjects to introduce science and engineering students to broad social and intellectual perspectives on their fields. It also offers more specialized subjects in the history of science and technology and in social and cultural studies of science and technology. Within each of these categories, students can choose both introductory and more advanced subjects.

Most STS undergraduate subjects may count toward the Institute Requirement in the Humanities, Arts, and Social Sciences. The program offers a number of HASS Distribution Requirement subjects and CI-H subjects, as well as a field of concentration.

The goal of the minor program is to give students majoring in engineering or one of the sciences a broader perspective on their fields: how they have evolved and how they fit into the wider context of society, culture, politics, and values.

The Minor Program in Science, Technology, and Society consists of six subjects as follows:

- Tier I: One HASS-D subject in STS
- Tier II: Four undergraduate STS subjects forming a coherent group relevant to the student’s major Course of study
- Tier III: One STS Reading Seminar (STS.091 or STS.092). Prerequisite is completion of one STS HASS-D subject or permission of the STS undergraduate advisor.

Dual Degree Program

For students who wish to integrate their professional study of engineering or science with a rigorous treatment of its relation to social and historical forces, STS offers a dual degree program in cooperation with the Schools of Engineering and Science. The object of this program is to give those students the full technical and scientific education provided by a science or engineering major, balanced with intensive study of the historical and social contexts of science and technology.

Students in the dual degree program must complete all the requirements of their majors as well as the STS requirements described below, and write a thesis in each field. Upon completion of all requirements, students receive a Bachelor of Science in Science, Technology, and Society and a Bachelor of Science in a specific field of engineering or science.

The STS requirements include 14 subjects as follows: one STS HASS-D subject; five other STS subjects; two reading seminars (STS.091 and STS.092); pre-thesis tutorial; the thesis; and four related HASS subjects forming a coherent group. Further details on the requirements of this dual degree may be obtained from the Department of Humanities and the STS undergraduate advisor.

Students must submit to the Registrar a petition that indicates the desire to work for this dual degree. The petition must be approved by faculty advisors in the two appropriate departments before students complete the entire program. Students who take a normal load of subjects may require five years to complete this program, but the majority of dual degree candidates finish their work in four years.

Joint Degree Program

Students who wish to integrate studies in STS and science or engineering in the context of a single degree program should consider this program. It includes a group of specially designated subjects offered by STS that provide a focus for interdisciplinary work. Central to this core is a year-long reading seminar (STS.091 and STS.092), which examines interactions of science, technology, and culture through reading, writing, and discussion of major works.

Students who take this degree must complete 10 subjects: one STS HASS-D subject; five other STS subjects; two STS Reading Seminars (STS.091 and STS.092); pre-thesis tutorial; and thesis.

Consult the degree chart for details on the requirements for this joint degree. Further details may be obtained from the Department of Humanities and the STS undergraduate advisor.

GRADUATE STUDY

In collaboration, STS, the History faculty, and the Anthropology Program offer a Program in History, Anthropology, and Science, Technology and Society (HASTS) leading to the PhD.

The objective of the program is to develop advanced competence in the study of science and technology from a historical and social scientific perspective. Students are expected to develop professional mastery of a field of history or one of the social sciences. They must also master the underlying concepts in science and engineering that relate to their special field of interest.

Doctoral students take at least 10 subjects in the doctoral program during their first two years. All graduate students take the introductory seminars, STS.210] and STS.250], in their first year. Students also choose several foundation subjects such as history of science or ethnographic methods. Finally, students choose several departmental seminars designed to offer more in-depth study of particular topics.

Upon the satisfactory completion of general examinations in the third year, students proceed to the writing of a dissertation, usually with the assistance of a multidisciplinary advisory committee.
Students from any academic discipline are invited to apply to the doctoral program.
For additional information about the graduate program, contact the academic administrator, History, Anthropology, and Science, Technology and Society (HASTS), STS, Room E51-185, MIT, 617-253-9759.

Inquiries
Additional information on the Program in Science, Technology, and Society may be obtained from the director, STS Program, Room E51-185, MIT, 617-253-4062.
For detailed descriptions of subjects in Science, Technology, and Society, see STS.001 to STS.910 in Part 3.

Faculty and Staff
Faculty and Teaching Staff
Rosalind H. Williams, PhD
Robert M. Metcalfe Professor of Writing
Director

Professors
Michael M. J. Fischer, PhD
Professor of Anthropology and Science and Technology Studies

Deborah K. Fitzgerald, PhD
Professor of the History of Technology

Kenneth Rogers Manning, PhD
Interim Dean, School of Humanities, Arts, and Social Sciences

Thomas Meloy Professor of Rhetoric and the History of Science

David A. Mindell, PhD
Frances and David Dibner Professor of the History of Engineering and Manufacturing

Theodore A. Postol, PhD
Professor of Science, Technology, and National Security Policy

Merritt Roe Smith, PhD
Leverett Howell and William King Cutten Professor of the History of Technology

Sherry Turkle, PhD
Abby Rockefeller Mauzé Professor of the Sociology of Science

Bachelor of Science in Science, Technology, and Society/Dual Degree/Course STS

General Institute Requirements (GIRs)  

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>[three subjects can be satisfied by subjects in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the Departmental Program]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>(REST) Requirement</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

Communication Requirement
The program includes a Communication Requirement of 4 subjects:
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program
Subject names below are followed by credit units, and by prerequisites if any

Required Subjects  
48

One STS HASS-D subject of at least 12 units

STS.ops Reading Seminar in Humanities, Science, and Technology I, 9*, HASS

STS.ops Reading Seminar in Humanities, Science, and Technology II, 9*, HASS, CI-M

STS.ThT Undergraduate Thesis Tutorial, 6

STS.ThU Undergraduate Thesis in Humanities, 12, CI-M; STS.ThT

Restricted Electives 81–108
A coherent group of five elective subjects in STS.
Four related subjects in humanities, arts, and social sciences (3 of which can be satisfied by HASS GIRs).

Departmental Program Units That also Satisfy the GIRs (30)

Unrestricted Electives 48–81

Total Units Beyond the GIRs Required for SB Degree 180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

Notes
*Prerequisites are listed in the subject description.
The full major in Science, Technology, and Society (STS) may be pursued only as a second degree program in conjunction with another degree program in a field of engineering or science.
For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
Associate Professors
David Kaiser, PhD
Associate Professor of the History of Science
Lecturer in Physics
Undergraduate Faculty Advisor
(On leave, fall)

Assistant Professor
David S. Jones, PhD, MD
Leo Marx Career Development Assistant
Professor of the History of Science

Adjunct Professor
John Durant, PhD
Adjunct Professor of Science, Technology, and Society

Visiting Professors
Manuel Castells, PhD
Distinguished Visiting Professor of Technology and Society
Jill Ker Conway, PhD
Professor of the History of Women
Thomas P. Hughes, PhD
Distinguished Visiting Professor of the History of Technology

Senior Lecturer
Leo Marx, PhD
William R. Kenan Professor of American Cultural History, Emeritus

Professors Emeriti
Louis Lawrence Bucciarelli, PhD
Professor of Engineering and Technology Studies, Emeritus
Loren R. Graham, PhD
Professor of the History of Science, Emeritus
Carl Kaysen, PhD
David W. Skinner Professor of Political Economy, Emeritus
Evelyn Fox Keller, PhD
Professor of History and Philosophy of Science, Emerita
Kenneth Keniston, PhD
Andrew W. Mellon Professor of Human Development, Emeritus
Leo Marx, PhD
William R. Kenan Professor of American Cultural History, Emeritus
Eugene B. Skolnikoff, PhD
Professor of Political Science, Emeritus
Leon Trilling, PhD
Professor of Aeronautics and Astronautics, Emeritus
Charles Weiner, PhD
Professor of the History of Science and Technology, Emeritus
The Program in Writing and Humanistic Studies provides students the opportunity to experiment with writing as a craft and as a means of self-expression. The program helps prepare students to communicate the results of their work forcefully and clearly to members of their professions and to larger audiences. All subjects in the program emphasize the development of writing skills and strategies. Some subjects, including those at advanced levels and those offered for distribution, require substantial reading.

Subjects in the program’s four areas—exposition and rhetoric, creative writing, science writing, and technical communication and new media studies—are taught at introductory and advanced levels. All subjects require repeated writing and revision. In addition, manuscripts are typically discussed in workshops and receive the written commentary of the instructor. Students are encouraged to schedule private conferences with their instructors.

Concentrations in writing establish a course of intensive study for prose, poetry, and fiction writers, or for engineers and scientists who expect writing to play a key role in their career development.

The Minor Program in Writing provides students with a structured opportunity to develop their expertise in one of the program’s four areas: exposition and rhetoric, creative writing, science writing, or technical communication and new media studies—while also exploring offerings in the other areas.

At the graduate level, the program offers a one-year master’s degree in science writing.

**Bachelor of Science in Writing/ Course 21W**

The Program in Writing and Humanistic Studies offers two undergraduate programs leading to the degree of Bachelor of Science in Writing. The curriculum in Creative Writing/Exposition and Rhetoric is designed to develop expertise in writing and reading a genre of the student’s choice (for example, fiction, poetry, essay), familiarity with related genres, and three-subject focused exposure to an allied discipline in the humanities, arts, and social sciences. This curriculum offers students a great deal of flexibility in designing their programs.

The curriculum in Science Writing/Technical Communication Studies is designed to develop mastery of these more specialized genres, to offer experience of the professional environments in which they are used, and to introduce related areas such as the history of technology and the structure of business organizations. Like the Creative Writing/Exposition and Rhetoric curriculum, it also requires a three-subject focused exposure to an allied field. In order to guarantee integration of these interdisciplinary elements, this curriculum places greater constraints on the design of individual programs.

**Minor Program in Writing**

The Minor Program in Writing consists of six subjects focusing on one of four areas: exposition and rhetoric; creative writing; science writing; or technical communication and new media studies, arranged into two levels of study as follows:

- **Tier I** One subject from the following:
  - 21W.730 Expository Writing
  - 21W.731 Writing and Experience
  - 21W.732 Introduction to Technical Communication
  - 21W.734J Writing About Literature
  - 21W.755 Writing and Reading Short Stories
  - 21W.756 Writing and Reading Poems

- **Tier II** Five subjects from among the remaining writing subjects

**Joint Degree Programs**

Joint degree programs are offered in writing in combination with a field in engineering or science (the 21E and 21S degrees). See the joint major programs listed under Humanities.

**Graduate Program in Science Writing**

The one-year Graduate Program in Science Writing is aimed at students who wish to write about science and technology for general readers, in ordinary newsstand magazines and newspapers, in popular and semi-popular books, on the walls of museums, or on television or radio programs. Students may be products of undergraduate science, engineering, journalism or writing programs; experienced journalists and freelance writers; working scientists or engineers; historians of science and technology; or other scholars, including those already holding advanced degrees.

The program is built around an intensive year-long advanced science writing seminar. In addition, students choose one elective each semester, write a substantial thesis, and complete an internship.

The graduate program maintains links to MIT’s Program in Science, Technology, and Society; to the Comparative Media Studies program; and to the Knight Science Journalism Fellowships program. For more information, see the descriptions of the Science, Technology, and Society and Comparative Media Studies programs in Part 2. See Interdisciplinary Research and Study in Part 1 for more information about the Knight Science Journalism Fellowships program.

**Communication Requirement**

Information about the new Communication Requirement is available under Undergraduate Education in Part 1. Additional details may be obtained from the Office of the Writing Requirement at 617-253-3039.

**Writing and Communication Center**

The MIT Writing and Communication Center offers free individual writing consultation on an appointment or drop-in basis to all members of the MIT community. In addition, the center gives mini-sessions each semester on a variety of writing topics, and also offers workshops for people for whom English is a second language. For further information, contact the Writing Center at 617-253-3090.

**Writing Across the Curriculum**

The Writing Across the Curriculum (WAC) staff of the Program in Writing and Humanistic Studies helps provide the integration of instruction and feedback in writing and speaking in subjects in all undergraduate departments and programs. The writing tutor program supports enhanced writing instruction in Communication Intensive in Humanities, Arts, and Social Sciences (CI-H) subjects. WAC lecturers collaborate with faculty in all schools in the teaching of Communication Intensive in the Major (CI-M) subjects.

Subjects in writing are numbered 21W.730 through 21W.899 in Part 3. Further information on subjects and programs may be obtained from the Program in Writing and Humanistic Studies Office, Room 14E-303, 617-253-7894.
Bachelor of Science in Writing/Course 21W

General Institute Requirements (GIRs)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td></td>
</tr>
<tr>
<td>(three subjects may be satisfied by subjects in the</td>
<td></td>
</tr>
<tr>
<td>Departmental Program)</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST)</td>
<td>8</td>
</tr>
<tr>
<td>Requirement</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td>17</td>
</tr>
</tbody>
</table>

Communication Requirement

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H);
- 2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program

<table>
<thead>
<tr>
<th>Subject names below are followed by credit units, and by prerequisites if any</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program 1: Creative or Expository Writing</td>
</tr>
<tr>
<td>Required Subjects</td>
</tr>
<tr>
<td>21WThT Writing and Humanistic Studies Pre-Thesis Tutorial, 6</td>
</tr>
<tr>
<td>21WThT Writing and Humanistic Studies Thesis, 12, CI-M; 21WThT</td>
</tr>
<tr>
<td>Restricted Electives</td>
</tr>
<tr>
<td>Seven subjects centered on creative or expository writing, of which one is</td>
</tr>
<tr>
<td>normally introductory (see Tier I of Minor Requirements), two subjects in</td>
</tr>
<tr>
<td>literature, and three related subjects from a second HASS discipline. One</td>
</tr>
<tr>
<td>subject must be designated as CI-M: 21W757, 21W758, 21W759, 21W760, 21W770,</td>
</tr>
<tr>
<td>21W771, 21W776, 21W777.</td>
</tr>
<tr>
<td>Program 2: Science Writing or Technical Communication and New Media Studies</td>
</tr>
<tr>
<td>Required Subjects</td>
</tr>
<tr>
<td>21W777 The Science Essay, 12, HASS, CI-M</td>
</tr>
<tr>
<td>21W778 Science Journalism, 12, HASS, CI-H</td>
</tr>
<tr>
<td>21W780 Communicating in Technical Organizations, 12, HASS</td>
</tr>
<tr>
<td>21W792 Science Writing and Technical Communication Internship, 12, HASS;</td>
</tr>
<tr>
<td>21W780 or 21W778</td>
</tr>
<tr>
<td>21WThT Writing and Humanistic Studies Pre-Thesis Tutorial, 6</td>
</tr>
<tr>
<td>21WThT Writing and Humanistic Studies Thesis, 12, CI-M; 21WThT</td>
</tr>
<tr>
<td>Restricted Electives</td>
</tr>
<tr>
<td>Five subjects in writing and related disciplines, of which one is normally</td>
</tr>
<tr>
<td>introductory (see Tier I of Minor Requirements), and three related subjects</td>
</tr>
<tr>
<td>in a second HASS discipline.</td>
</tr>
</tbody>
</table>

Departmental Program Units That also Satisfy the GIRs

| (27–36) | |
| Unrestricted Electives                                                    |
| Program 1                                                                 | 54–81    |
| Program 2                                                                 | 54–69    |

Total Units Beyond the GIRs Required for SB Degree

| 180 |
| No subject can be counted both as part of the 17-subject GIRs and as part  |
| of the 180 units required beyond the GIRs. Every subject in the student’s  |
| departmental program will count toward one or the other, but not both.    |

Notes

The full major in science writing or technical communication studies may be pursued only as a second degree program in conjunction with another degree program in a field of engineering or science.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
**Senior Lecturer**
Edward Barrett, PhD
Senior Lecturer in Writing

**Lecturers**
Cherie Abbanat, MA
Atissa Banuazizi, MA
Karen Boiko, MA
Harlan Breindel, MA
Mary Caulfield, BA
B. D. Colen, BA
Jane Abbott Connor, MA
William Corbett, BA
Director, Student Writing Activities
Jennifer Craig, MA
David Custer, BA
Thomas Delaney, MA
Robert Doherty, MA
Rebecca Faery, PhD
Director, First Year Writing
Erica Funkhouser, MA
William Haas, PhD
Hillary Joyce-Scott, MFA
Nicole Kelley, MFA
Sarah King, PhD
Neal Lerner, EdD
Shariann Lewitt, MFA
Lucy Marx, MA
Janis Melvold, PhD
Marilee Ogren-Balkema, PhD
Karen Pepper, PhD
Mya Poe, MA
Director, Technical Communication
Boyce Rensberger, MS
Leslie Ann Sulit Roldan, PhD
Thalia Rubio, MEd
Susan Ruff, BA
Cynthia Taft, PhD
Donald Unger, PhD
Lydia Volaitis, PhD
Andrea Walsh, PhD
Mary Zoll, PhD

**Research Staff**

**Senior Research Scientist**
Sonal Jhaveri, PhD

**Research Associate**
Philip Alexander, MS

**Professors Emeriti**
Anita Desai, BA
John E. Burchard Professor of Humanities, Emerita
Robert Reynolds Rathbone, AM
Professor of Technical Communication, Emeritus
Cynthia Griffin Wolff, PhD
Class of 1922 Professor of Literature, Emerita
The School of Humanities, Arts, and Social Sciences offers a number of graduate and undergraduate programs embracing several academic disciplines. In general, these programs are staffed collaboratively by faculty members from various departments and fields in the School of Humanities, Arts, and Social Sciences and, in some cases, from the Institute’s other schools as well.

Concentrations within the Humanities, Arts, and Social Sciences Requirement are available in most of these areas, with degree programs available in some of them.

Full information on subjects offered, names of participating faculty, and specific concentration and major requirements in these programs may be obtained from the individual program coordinator or from the HASS Information Office, Room 21E-340, 617-253-4441. The lists of subjects also appear in the Guide to the Humanities, Arts, and Social Sciences.

Brief descriptions of the programs follow.

American Studies
American Studies at MIT offers students the opportunity to organize subjects from various fields (e.g., history, anthropology, literature, political science, music, art, and architecture, and urban studies) into personally constructed interdisciplinary programs as a way of gaining an integrated understanding of American society and culture.

American Studies is a field of concentration; it is also available as the humanities component of a joint major program (the 21E and 21S degrees), or as a full major by special arrangement. American Studies majors work out a coherent program of study with an advisor, usually including two subjects each in literature and history, although variations are possible. Major programs can center on a particular interest or aim more broadly at a comprehensive knowledge of various aspects of American life and culture.

The coordinator of American Studies is Professor Christopher Capozzola, Room E51-180, 617-452-4960, capozzol@mit.edu.

Ancient and Medieval Studies
Through a wide variety of subjects drawn from a number of disciplines, this program provides a curricular framework for exploring topics in ancient and medieval studies which range from the history of ideas and institutions to that of material artifacts, literature, and certain of the original languages. The program spans the 6,500 years between 5000 BC and 1500 AD.

This program’s goal is to develop knowledge and understanding of the more distant past both for itself, in its uniqueness, and as an object of specifically modern questions and methods of inquiry. The program has an interest in the structure of institutions and social systems, and in relationships between the social order and learned traditions, values, ideologies, and ideas. Ancient and medieval studies derive a special claim to our interest from the fact that the record is so full and multiform and that much of it is of exceptionally high quality at once in substance and form.

Ancient and Medieval Studies is available as a concentration, a minor, and as a major department within Course 21. Individual programs are to be determined in consultation with Professor Anne McCants, Room E51-175, 617-258-6669.

Minor in Applied International Studies
The interdisciplinary HASS Minor in Applied International Studies prepares students for an increasingly global economy and international research environment by integrating international learning into their course of study. The six-subject minor is organized into three areas: language and culture; international politics, economics, and history; and third, a set of courses that prepares students for experiences abroad and helps them to reflect on their work, research, or study-abroad experience after the return to campus. The minor requires a stay abroad, which should be planned in consultation with the minor advisor. See the program description under Political Science in Part 2.

Additional information can be obtained from Bernd Widdig, minor advisor, Center for International Studies, E36-762, 617-253-3925, bwiddig@mit.edu.

Middle East Program at MIT
The Middle East Program at MIT, an interdisciplinary course of study taken in conjunction with the graduate program in a student’s chosen department, focuses on technology, development, and public policy. The program enables students with an interest in the Middle East (including North Africa and South Asia) to develop an expertise in the area within the context of a coherent program of study. It equips students with an understanding of the processes of socioeconomic change, technological development, political change, environmental management, knowledge networking, institutional development, sustainability strategies, and international business and investment patterns in the region.

This program draws on MIT’s unique strengths in science and technology to offer a course of study distinct from a conventional “area studies” approach to the Middle East. The emphasis at present is on challenges of design and development in the reconstruction of the region following violent conflicts, as well as on innovations and applications of advances in information technology and knowledge e-networking to support development objectives.

The program is based on the participation of faculty from the Departments of Political Science, Civil and Environmental Engineering, and Urban Studies and Planning; the History Section of the Department of Humanities; the Sloan School of Management; the Program in Science, Technology and Society; and the Aga Khan Program in Islamic Architecture.

For further information, contact Professor Nazli Choucri, Department of Political Science, Room E53-493, 617-253-6198, nchoucri@mit.edu.

Program in Psychology
Psychology, the study of human mental life and behavior, is represented at MIT as a program in the School of Humanities, Arts, and Social Sciences, and as a concentration within the undergraduate HASS Requirement. Faculty and subjects in psychology are found in many MIT departments, including Brain and Cognitive Sciences, Management, History, and STS. Students who wish to concentrate in psychology take a set of subjects from these departments, chosen in consultation with the concentration officer for the Program in Psychology (details are available at the HASS office).

Students who wish a more substantial education in the field may minor in psychology. A minor involves six subjects starting with 9.00 Introduction to Psychology. Detailed information about the minor may be found in the description of undergraduate study in the Department of Brain and Cognitive Sciences.
In addition to taking psychology subjects, undergraduates may take advantage of a wide range of research opportunities (generally via the Undergraduate Research Opportunities Program). Students should contact UROP coordinators from specific departments about projects currently available.

Psychology exists as a major at MIT only as a major departure within Course 21.

For other information about the Program in Psychology, contact Professor Mary Potter, Room 46-4125, 617-253-5526, mpotter@mit.edu.

Minor in Public Policy

The interdisciplinary HASS Minor in Public Policy is intended to provide a single framework for students interested in the role of public policy in the field of their technical expertise. The description of undergraduate study in the Department of Urban Studies and Planning in Part 2 contains a detailed description and list of requirements for this minor.

The minor advisors are Professor Andrea Campbell, Room E53-461, 617-452-2295, acampbel@mit.edu, in Political Science, and Professor David Laws, Room 9-326, 617-253-2084, dlaws@mit.edu, in Urban Studies and Planning.

Women’s Studies Program

Women’s Studies is an interdisciplinary inquiry into the significance of gender in human society and thought, both in the United States and around the world. Drawing on thirty years of scholarly work centered on gender analysis as well as research in many traditional fields, the program explores questions such as how women and men learn their gender roles; how different societies define women and men; and how ideas of sex and gender shape and are shaped by language, individual behavior, and social institutions such as law, religion, and education. Students explore the varied roles gender has played in different cultures, times, intellectual disciplines, and forms of creative expression. Debates over sexuality, reproduction, feminism, masculinity, the roles of women in history, politics, and science, and the intersections of gender with other social categories such as race, class, ethnicity are all topics addressed within this interdisciplinary field.

Most Women’s Studies subjects are cross-listed with other departments and are available to students in a wide range of fields of study. Through classes, UROPs, and events, both undergraduate and graduate students gain new perspectives on other disciplines such as computer science, law, philosophy, theater, management, literature, urban studies, psychology, and history. Women’s Studies subjects are open to all students.

The curriculum includes a core subject, Introduction to Women’s and Gender Studies, and a selection of subjects from many departments at the Institute, listed in the Special Programs section of Part 3. A full major (known as a major departure) is available by special arrangement. Women’s Studies also offers a minor program and a concentration.

The Minor Program in Women’s Studies is designed for students who, in addition to the focus of their major program of study, are seeking a fuller understanding of the ways in which gender and gender constructs have shaped human understanding of self and community. The minor program consists of six subjects, one of which may be taken at Harvard or Wellesley with the permission of the director, arranged into three levels of study as follows:

<table>
<thead>
<tr>
<th>Tier</th>
<th>Required Introductory Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier I</td>
<td>Required Introductory subject:</td>
</tr>
<tr>
<td>SP.401</td>
<td>Introduction to Women’s and Gender Studies</td>
</tr>
<tr>
<td>Tier II</td>
<td>Four subjects, at least one of which is drawn from each category:</td>
</tr>
<tr>
<td></td>
<td>Humanities and the arts</td>
</tr>
<tr>
<td></td>
<td>Social and natural sciences</td>
</tr>
<tr>
<td>Tier III</td>
<td>One advanced seminar:</td>
</tr>
<tr>
<td>SP.412</td>
<td>Feminist Political Thought or an upper-level Women’s Studies course as determined by the director</td>
</tr>
</tbody>
</table>

For more information, see Interdisciplinary Research and Study in Part 1 or contact the coordinator, Women’s Studies, Room 14E-316, 617-253-8844, womens-studies@mit.edu, or visit http://web.mit.edu/womens-studies/www/.

Graduate Consortium in Women’s Studies

The Graduate Consortium in Women’s Studies (GCWS) is a pioneering effort to advance women’s studies scholarship by offering a series of interdisciplinary and cross-university team-taught graduate seminars. The consortium includes Boston College, Brandeis University, Harvard University (Graduate School of Arts and Sciences, Harvard Divinity School, and the Graduate School of Education), MIT, Northeastern University, Simmons College, Tufts University, and the University of Massachusetts Boston. The Consortium is currently administered at MIT.

For more information, see the section on Graduate Education in Part 1; contact the coordinator of GCWS, Room 16-287, 617-324-2085, or visit http://web.mit.edu/gcws/.
The following Minors in Regional Studies have been approved: African and African Diaspora Studies, East Asian Studies, European Studies, Latin American Studies, Middle Eastern Studies, and Russian Studies. These interdisciplinary programs provide MIT undergraduates with a valuable opportunity to acquire knowledge of a particular country or region in conjunction with proficiency in a foreign language. This better prepares them for academic, business, and government careers in a world where regions and countries are increasingly interdependent.

Because the nature of these minors is cross-disciplinary, combining foreign language study with humanities, arts, and social sciences, they are arranged into the following four areas of study:

Area I: Language (Intermediate level)
Area II: Humanities and the Arts
Area III: Social Sciences
Area IV: Historical Studies

Students are required to take six subjects (at least three of which must be MIT subjects) in the following configuration: two intermediate-level language subjects (Area I) and four other subjects, chosen from at least two of the other three areas. If a student already has achieved the equivalent of intermediate-level proficiency, he or she can take either two more advanced-level language subjects or two more subjects from Areas II, III, or IV in place of the intermediate-language subjects. Languages not presently taught at MIT may be taken at Harvard or Wellesley, or elsewhere during the summer with the permission of the minor advisor.

Details on each of the minors are given below. Lists of subjects that are appropriate for a HASS minor in each of the regional studies, as well as additional information about minors, advisors, etc., can be obtained from the relevant minor advisor or from the HASS Education Office, Room 14N-408, 617-253-4441.

Minor in African and African Diaspora Studies
The Minor in African and African Diaspora Studies is designed for students interested in the cultures and experiences of the peoples of African descent on the continent or elsewhere. The minor includes study of economic and political systems as they reflect the African continent and areas of the African diaspora, and the histories, languages, and literatures of Africans and peoples of African descent elsewhere. All of Africa falls within the geographical scope of the minor. A student may concentrate on a particular region or on any of the broad groupings of African cultures, such as Arabic-speaking, Anglophone, Francophone, or Lusophone Africa. Equally, a student choosing to focus on the African diaspora may concentrate on any group of African-descended populations in the Americas. Students focusing on either principal area (Africa or the African diaspora) must also take at least one subject which deals with the other area or with interactions between them.

The goal of the minor program is to emphasize the importance of Africa and people of African descent in world cultural, economic, and social developments, and to provide a balance between language, humanistic, historical, and contemporary study.

Students are expected to have two intermediate (Levels III and IV) subjects in either the official language of the region of study or in an indigenous African language. In cases where the student is specializing in Anglophone Africa or an English-speaking region of the diaspora, and does not undertake study of an indigenous language, or is a native speaker of the official language(s) of a country or region of emphasis, this component would be replaced by literature or other humanities subjects.

Additional information can be obtained from the minor advisor, Professor Christine Walley, Room 16-231, 617-258-7908, or from the HASS Education Office, Room 14N-408, 617-253-4441.

Minor in East Asian Studies
The Minor in East Asian Studies is designed for students interested in the language, history, politics, and culture of Asia. East Asia includes the countries which share a common background in the Chinese classical tradition: present-day People’s Republic of China, Taiwan, Korea, Japan, and Vietnam; but the core offerings at MIT cover China and Japan. The goal of the minor program is to provide balanced coverage of language, humanistic, and social science offerings on the region and to expose students to comparative perspectives.

The language requirement can be satisfied by taking two intermediate (Levels III and IV) subjects in an East Asian language (Mandarin Chinese, Japanese, Korean, or Vietnamese). Chinese and Japanese are now taught at MIT.

Additional information can be obtained from the minor advisor, Professor Peter C. Perdue, Room E51-291, 617-253-3064, or from the History Office, Room E51-285, 617-253-9846, or the HASS Education Office, Room 14N-408, 617-253-4441.

Minor in European Studies
The Minor in Modern European Studies is designed for students who are seeking a fuller understanding of the forces which have shaped modern Europe. The geographical and chronological scope of the minor program has been made deliberately broad to accommodate the wide variety of student interests. Subjects range in content from the Renaissance to the present, and from the British Isles to Central Europe. A student can choose to focus on one particular country or on a broader region, with a comparative perspective. Given the breadth of offerings, the student should consult closely with his or her minor advisor in order to devise a coherent program of study.

Students are expected to demonstrate intermediate-level proficiency in a modern European language other than English by taking two intermediate (Levels III and IV) subjects, but they need not concentrate their other subjects on the country associated with that language.

Additional information can be obtained from the minor advisor, Professor Charity Scribner, Room 14N-320, 617-452-2800, or from the HASS Education Office, Room 14N-408, 617-253-4441.

Minor in Latin American Studies
The Minor in Latin American Studies is designed for students interested in the languages, history, politics, and cultures of Latin America. The core offerings at MIT largely concentrate on those areas formerly colonized by Spain, although students are not required to focus their study exclusively on these areas. They are encouraged to develop a program that is both international and comparative in perspective and that takes into account the heterogeneous cultural experiences of people living in the vast territory loosely termed Latin America, as well as of those people living in the United States who identify themselves as Latino.
Two intermediate (Levels III and IV) subjects, either in Spanish or Portuguese, satisfy Area I. MIT offers Levels III and IV of Spanish every term and those wishing to study Portuguese may do so at Harvard University. All students opting for the minor are required to take 21F.084J/17.541J/21A.224J Introduction to Latin American Studies. Additional information can be obtained from the minor advisor, Professor Elizabeth Garrels, Room 14N-303, 617-253-9688, or from the HASS Education Office, Room 14N-408, 617-253-4441.

Minor in Middle Eastern Studies

Middle Eastern Studies at MIT offers students the opportunity to explore the connections among culture, society, politics, economics, technology, and environment in the Middle East, including North Africa. MIT offers a number of subjects open to undergraduates which provide a variety of perspectives on the ancient, Islamic, and modern Middle East. The goal of the HASS Minor Program in Middle Eastern Studies is to lead the student from the basic language into survey subjects and then into more focused studies of individual countries or specific historical periods and to encourage analysis of the main methodological and conceptual issues in Middle Eastern Studies.

Two intermediate (Levels III and IV) subjects in one of the following Middle Eastern languages are required: Arabic, Hebrew, Persian, or Turkish. Because MIT does not offer instruction in these languages, students may satisfy the Area I language requirement at Harvard University. They may satisfy the language requirement at other institutions provided they receive permission in advance from the HASS minor advisor in Middle Eastern Studies.

Additional information can be obtained from the minor advisor, Professor Philip S. Khoury, Room E51-255, 617-253-3255, or from the HASS Education Office, Room 14N-408, 617-253-4441.

Minor in Russian Studies

The Russian Regional Studies Minor is intended for students seeking an interdisciplinary program of study centered on Russia and the former Soviet Union. The historical, cultural, and political importance of Russia itself, as well as the nature of MIT’s subject offerings, suggest a primary concentration on that particular country, the dominant element in the former Soviet Union.

The program is, however, regional in spirit, given both the multinational and multicultural role of the Russian Republic and the likelihood that other former Soviet Republics choose to remain in political and economic association with it.

Two intermediate (Levels III and IV) subjects in the Russian language are required to satisfy Area I. These subjects are not offered at MIT, but may be taken at Harvard University or Wellesley College through cross-registration. For more information, see Undergraduate Education in Part 1.

Additional information can be obtained from the minor advisor, Professor Elizabeth Wood, Room E51-282, 617-253-3255, or from the HASS Education Office, Room 14N-408, 617-253-4441.
The MIT Sloan School of Management, like the rest of MIT, catalyzes innovation through research and education. As one of the world’s leading business schools, MIT Sloan seeks to develop principled, innovative leaders who improve the world. Sloan graduates are particularly good at building cutting-edge products, services, markets, and organizations—delivering the advances essential for competitive survival and for economic and social progress.
The mission of the MIT Sloan School of Management is to develop principled, innovative leaders who improve the world and to generate ideas that advance management practice.

To accomplish this, the School

- Offers premier programs for shaping leaders who will create, redefine, and build cutting-edge products, services, markets, and organizations
- Collaborates across MIT to capitalize on and contribute to the Institute’s distinctive intellectual excellence and entrepreneurial culture
- Attracts, develops, and retains outstanding faculty and staff who lead the world in management education and research
- Enrolls students with integrity, strong leadership potential, high aspirations, and exceptional intellectual ability
- Fosters a cooperative and adventurous learning community that includes alumni and business partners, works on important problems, and is based on mutual respect, rigorous analysis, and high ethical standards

History

The MIT Sloan School grew out of a curriculum in engineering administration—Course 15—that was first offered to MIT undergraduates in 1914. A program leading to a master’s degree in management was established in 1925. The world’s first university-based executive education program, the Sloan Fellows Program, had its beginnings at MIT in 1931 under the principal sponsorship of Alfred P. Sloan, Jr., the 1895 MIT graduate in electrical engineering who rose to the top of the General Motors Corporation. Sloan endowed the pioneering program in 1938. In 1952, a further grant from the Sloan Foundation made possible the creation of the MIT School of Industrial Management—charged with the education of “the ideal manager.” The School was renamed in honor of Mr. Sloan in 1964.

New Directions

MIT Sloan’s array of top-ranked undergraduate, graduate, and executive programs are well known for drawing on the creative and collaborative approaches common to engineering, behavioral science, economics, and management science to give managers a competitive edge. In our diverse education and research programs, we work with industry to develop the basic knowledge, insights, tools, and techniques that are shaping the future of the practice of management.

Among MIT Sloan’s key strengths are its exceptionally close ties with other world-class departments at MIT, especially in fields crucial to business, including economics, engineering, and science. One manifestation of this interdisciplinary approach is Leaders for Manufacturing, an educational and research collaboration with the School of Engineering and industry partners that is transforming the practice of manufacturing and manufacturing education. Other examples include the medical innovations course, conducted in partnership with MIT Sloan, the School of Engineering, and doctors at Massachusetts General Hospital, and the new Biomedical Enterprises program.

With a focus on the future of management, MIT Sloan has been aggressive in developing leading edge research programs that have an impact on the emerging practice of business. The School has been a leader in developing the concepts of financial engineering that underlie today’s financial markets, for example. It also conducts pioneering research in the management of technology and offers the nation’s leading master’s program for executives in this important area. Recently, MIT Sloan launched an exciting Executive Education program, Leading Innovative Enterprise: Strategies for Growth in the Life Sciences.

Reflecting a world characterized by increasing economic globalization, MIT Sloan is itself an international community. Approximately one-third of the MBA class and close to half of all executive education participants come from outside the United States, and diverse research/educational collaborations have been developed with Europe, Mexico, and Asia. In addition, the School has a strong network of alumni in more than 100 countries.

As one of the world’s preeminent management schools, MIT Sloan strives to prepare its students to be innovative leaders in a rapidly changing world. In an increasingly competitive environment, MIT Sloan must continually listen to the marketplace, explore new directions, and use this knowledge to develop new products, services, and processes quickly and efficiently. To maintain its leadership, MIT Sloan continues to drive change and innovation in a number of areas:

Entrepreneurship. The MIT Entrepreneurship Center, housed at MIT Sloan, aims to inspire, train, and coach new generations of entrepreneurs to create successful high-tech ventures. The center’s educational programs, especially New Enterprises, Entrepreneurship Lab, and Entrepreneurship Lab courses, are designed to give students the experience, skills, and network they need to turn their ideas into opportunities for new ventures and then to make those ventures successful. The center continues to work with leading practitioners and build its entrepreneurship faculty, who also conduct research on the dynamic process of high-tech venture development.

Global Initiatives. A top priority for MIT Sloan is to widen the international reach of its educational and research initiatives. MIT Sloan has international MBA programs in collaboration with China’s Sun Yat-sen, Fudan, Tsinghua, Yunnan, and Lingnan universities. MIT Sloan also hosts Chinese university faculty to help them absorb and apply MIT Sloan’s approach to management education. The School also works with Nanyang Technological University in Singapore, the Epoch Foundation in Taiwan, The Sungkyunkwan University in Korea, and Instituto Tecnológico y de Estudios Superiores in Mexico.

Research Centers

MIT Sloan’s interdisciplinary research centers include:

- Center for Computational Research in Economics and Management Science
- Center for Coordination Science
- Center for eBusiness@MIT
- Center for Energy and Environmental Policy Research
- Institute for Work and Employment Research
**Degrees Offered in the MIT Sloan School of Management**

<table>
<thead>
<tr>
<th>Management</th>
<th>Course 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB</td>
<td>Management Science</td>
</tr>
<tr>
<td>MBA</td>
<td>Management</td>
</tr>
<tr>
<td>SM</td>
<td>Management Science</td>
</tr>
<tr>
<td>SM</td>
<td>Management of Technology</td>
</tr>
<tr>
<td>SM/MBA</td>
<td>Engineering/Management—Leaders for Manufacturing</td>
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<tr>
<td>PhD</td>
<td>Management</td>
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</tbody>
</table>

**Operations Research**

<table>
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<tr>
<th>SM</th>
<th>Operations Research¹</th>
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<tbody>
<tr>
<td>PhD</td>
<td>Operations Research¹</td>
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</table>

**Systems Design and Management**

<table>
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<tr>
<th>SM</th>
<th>Engineering and Management¹</th>
</tr>
</thead>
</table>

Note: Many departments make it possible for a graduate student to pursue a simultaneous master’s degree.

¹The Operations Research Center is an interdepartmental center affiliated with a variety of departments from the MIT Sloan School of Management, the School of Engineering, the School of Science, and the School of Architecture and Planning. See the section on Interdisciplinary Graduate Programs in Part 2 for more information on these programs.

²The Systems Design and Management Program is offered jointly by the School of Engineering and the MIT Sloan School of Management. See the section on the Engineering Systems Division in Part 2 for more information.

Recent and current research topics include IT governance, IT infrastructure, IT architecture, IT portfolios, IT outsourcing, and IT-related risk. CISR disseminates this research via electronic briefings, published articles, working papers, an annual summer conference, research workshops, and executive education short courses.

For more information about the center, contact Chris Foglia, 617-253-6657, cisr@mit.edu, or visit [http://mitsloan.mit.edu/cisr/](http://mitsloan.mit.edu/cisr/).

**The Information Technology Group** engages students of computer science, sociology, economics, psychology, engineering, organizational science, and other disciplines in understanding how information technology continues to transform the way people work, communicate, and learn.

For more information about the Information Technologies Group, contact sloan-it-www@mit.edu, or visit [http://web.mit.edu/sloan-it/www/](http://web.mit.edu/sloan-it/www/).

**Publications**

MIT Sloan produces publications that enjoy robust readerships within the MIT community, across the country, and around the world. *MIT Sloan Management Review* is a quarterly subscription-based journal for professional managers. More information about the magazine is presented on the web at [http://mitsloan.mit.edu/smr/](http://mitsloan.mit.edu/smr/).

*MIT Sloan* is the newly designed alumni magazine. Seeking to better connect alumni to the School and to each other, the magazine contains news features, faculty articles, student and alumni profiles, and class notes.

In addition, MIT Sloan maintains a newly redesigned website that provides access to a rich and detailed range of news and information about the School, its activities, and its resources. The website is available at [http://mitsloan.mit.edu/](http://mitsloan.mit.edu/).

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Deputy Dean
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Senior Associate Dean
Donna M. Behmer, MEd
Senior Associate Dean, Finance and Administration
Bachelor of Science in Management Science/Course 15

The MIT Sloan School of Management offers an undergraduate degree program in management science. It is a cutting-edge program designed to prepare students for top jobs in today’s technologically oriented business world. By combining General Institute Requirements with subjects at the MIT Sloan School of Management, students learn a unique combination of technical and management skills that allow them to excel in such high-demand areas as web-based commerce, financial engineering, market analysis, and software development.

In recent years, the field of management science has grown rapidly in conjunction with advances in computer technology, in methods for collecting and structuring large quantities of data, in mathematical programming, and in the building of sophisticated mathematical models. The MIT Sloan School’s undergraduate program develops necessary competence in the underlying disciplines of mathematical programming and modeling, statistics, and computer technology. The program also provides a strong background in the associated disciplines of managerial psychology and economics, and demonstrates applications from a variety of functional areas of management. Beyond this, each student selects a concentration of four subjects in information technologies, operations research, marketing science, or finance.

MIT Sloan undergraduates take most management electives at the graduate level, alongside MBA and doctoral students. This arrangement provides an excellent opportunity for undergraduates to learn from students with previous business experience. A degree in management science gives students the best of both worlds—technical excellence and managerial focus.

Minor Program in Management
The Minor in Management is intended to provide undergraduates with an understanding of the economic, business, human, social, and organizational dimensions of scientific and technological enterprise. Its emphasis on management per se differs from that of the SB degree program in management science.

Bachelor of Science in Management Science/Course 15

General Institute Requirements (GIRs)subjects 6

Science Requirement
Humanities, Arts, and Social Sciences Requirement [two subjects can be satisfied by 14.01 and 14.02 in the Departmental Program] 8

Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 6.041 and 18.06 in the Departmental Program] 2

Laboratory Requirement [can be satisfied by 15.301 in the Departmental Program] 1

Total GIR Subjects Required for SB Degree 17

Communication Requirement
The program includes a Communication Requirement of 4 subjects: 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and 2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects
1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; 18.01 57–75
6.041 Probabilistic Systems Analysis, 12, REST; 18.02
14.01 Principles of Microeconomics, 12, HASS
14.02 Principles of Macroeconomics, 12, HASS
15.053 Introduction to Optimization, 12; 18.06*
15.075 Statistical Thinking and Data Analysis, 12; 6.041*, 18.06
15.279 Management Communication for Undergraduates, 12, CI-M
15.301 Managerial Psychology Laboratory, 15, LAB, CI-M
15.501 Corporate Financial Accounting, 12; 14.01
18.06 Linear Algebra, 12, REST; 18.02
6.001 Structure and Interpretation of Computer Programs, 15, REST
15.351 Managing Innovation and Entrepreneurship, 9
15.401 Finance Theory I, 9
15.760 Introduction to Operations Management, 6; 15.060*(1)
and
15.762 Supply Chain Planning, 6, 15.760*(1)
or
15.763 Manufacturing System and Supply Chain Design, 6; 15.760*(1)
15.812 Marketing Management, 9; 14.01

Concentration Subjects:
Four specified subjects in one of the following concentrations: Finance, Information Technologies, Marketing Science, Operations Research

Departmental Program Units That also Satisfy the GIRs (60)

Unrestricted Electives 54–72

Total Units Beyond the GIRs Required for SB Degree 180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

Notes
*Alternate prerequisites are listed in the subject description.

(1) 15.760, 15.762, and 15.763 are half-term subjects. 15.760 together with either 15.762 or 15.763 counts as a single subject.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
The minor consists of six subjects, four required:

14.01 Principles of Microeconomics
15.51 Corporate Financial Accounting
15.668 People and Organizations
15.812 Marketing Management

Plus two subjects from among the following restricted electives:

15.351 Managing Innovation and Entrepreneurship
15.401 Finance Theory I
15.667 Negotiation and Conflict Management
15.821HT Listening to the Customer
15.822HT Strategic Market Measurement
15.034 Applied Econometrics and Forecasting for Management
15.053 Introduction to Optimization
15.054J The Airline Industry (same subject as 1.2321, 16.71J, ESD.217J)
15.075 Statistical Thinking and Data Analysis
15.223HT Global Markets, National Policies and the Competitive Advantages of Firms
15.521HT Management Accounting and Control
15.535 Business Analysis Using Financial Statements
15.568 Practical IT Management
15.665 Power and Negotiation
15.670HT Leadership and Change
15.760HT Introduction to Operations Management
15.874 System Dynamics for Business Policy

Note: subjects marked "HT" are 6-unit, half-term subjects. Each HT subject counts as one-half of an elective. Other listed subjects each count as one elective.

Interdepartmental Students
MIT students from other departments are welcome to take unrestricted elective courses at MIT Sloan, if they have taken the listed prerequisites. All students must participate in the MIT Sloan bidding system. Information about the process is available on the bidding website at https://sloanbid.mit.edu/. Bidding occurs at the same time as online WebSIS pre-registration in December and May for the following terms. The MIT Sloan course schedule is available online, as are most class syllabi, to assist students in bid point allocation. Staff in Sloan Educational Services, Room E52-101, 617-253-1510, are always available to assist interdepartmental students and provide information about MIT Sloan classes and the bidding system.

Inquiries
For additional information about the undergraduate curriculum, students may consult the Undergraduate Program Office, Room E40-161, MIT, 617-253-8614.

GRADUATE STUDY
The MIT Sloan School of Management offers opportunity for graduate study leading to the degrees of Master of Business Administration, Master of Science in Management, Master of Science in Management of Technology, and Doctor of Philosophy.

Entrance Requirements for Graduate Study
Applications are welcome from college graduates in all areas of concentration—the humanities, social sciences, physical sciences, and engineering—but matriculants must have completed formal subjects in calculus and in economics. The minimum level of preparation is normally a one-year subject in economic theory and a one-year subject in calculus. If these subjects have not been taken in a previous academic program, they may be covered by formal subjects prior to enrollment.

All applicants, including those from foreign countries, must take the Graduate Management Admission Test (GMAT). Information is available from the Graduate Management Admission Council, Educational Testing Service, Princeton, New Jersey 08541. GRE scores may be used in place of GMAT scores only for the doctoral program and for LFM applicants applying through the School of Engineering.

Master of Business Administration and Master of Science in Management
The MIT Sloan School MBA Program offers a course of study in graduate business education, leading to a master’s degree in Business Administration (MBA) or Master of Science in Management (SM). Degree candidates are admitted in September to a program of study extending over two consecutive academic years. MBA degree candidates must complete a required core plus 144 units of H- or G-level elective subjects. Residency for four consecutive academic terms is required. Degree candidates must also fulfill research and leadership requirements through activities in the mid-semester Sloan Innovation Period and through elective coursework.

The MBA curriculum is designed for maximum flexibility, allowing students to create an individual program best suited to their needs and career interests. During the first term, students take a sequence of core subjects with the option of one elective course. After the first term, students have a wide range of elective course choice.

Practical exposure to management takes place in the MIT Sloan School through a variety of activities. Students in the MBA Program are expected to spend the summer between their first and second years working in some activity that contributes to their understanding of and effectiveness in dealing with management problems. During the academic year, some MBA candidates work as paid research assistants for members of the faculty, or become involved with them in the consulting activities that they carry on for government, firms, and other public and private organizations. Each semester, MIT Sloan faculty members offer research workshops during the Sloan Innovation Period. In addition, many students choose topics for their master’s theses or project work that involve research in the practice of management in particular organizations, industries, or sectors. Corporate leaders are often invited to work with students, either through guest lectureships in various classes or through interaction with one of the MIT Sloan student organizations such as the Finance Club.
the Media Tech Club, or the MIT Sloan Leadership Forum.

System Design and Management Program: Master of Science in Engineering and Management

Jointly sponsored by the School of Engineering and the MIT Sloan School, the System Design and Management (SDM) Program targets experienced engineers and product development professionals who seek to build upon their technical background and advance to positions of leadership in their careers.

The SDM program was created in 1996, in response to a critical need expressed by government and industry to provide future engineering leaders with an educational experience that combines an engineering systems perspective with the essentials of a management education. The program has focused on developing competencies in the areas of systems thinking, management skills, leadership, and an end-to-end understanding of systems development.

SDM is offered in three formats, including a 13-month full-time on-campus program and two career-compatible 24-month programs—half-time on campus for local area commuter students and a distance delivery option via synchronous video conferencing. SDM is the only MIT degree program that can be completed primarily through distance education.

Program applicants have significant engineering and/or managerial experience, in addition to a scientific or engineering education. On average, SDM student-fellows have about 10 years of work experience. The program participants come from both private and government institutions, either as company sponsored, or as self-sponsored students. A majority of SDM students have advanced degrees in other fields, and over half come from countries other than the United States.

The SDM Program begins in January. Applications are accepted on a continuous basis, with an early notification deadline of May 15 and a final cutoff of October 15 for admission to the next cohort. For additional information, contact the SDM Program Office, Room E40-315, 617-253-1055, sdm@mit.edu, or visit http://sdm.mit.edu/. See also the Engineering Systems Division section in Part 2.

Leaders for Manufacturing Program: Dual Master’s Degrees in Management and Engineering

The Leaders for Manufacturing (LFM) Program combines graduate education in engineering and management for those with two or more years of work experience who aspire to leadership positions in manufacturing or operations companies. This rigorous 24-month program combines subjects in technology and management. A required 6.5-month internship provides opportunity to complete a research project on site at one of LFM’s partner companies. The internship leads to a dual-degree thesis, culminating in two master’s degrees—an SM or MBA and an SM in Engineering. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering master’s programs in Aeronautics and Astronautics, Biological Engineering, Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering and Computer Science, Engineering Systems, Materials Science and Engineering, and Mechanical Engineering. For general requirements and application procedures, visit the LFM website at http://lfm.mit.edu/.

Doctor of Philosophy

The purpose of the MIT Sloan School’s PhD program is to prepare students for careers in teaching and research or, to a lesser extent, for positions requiring advanced research and analytical capabilities. The PhD program provides the opportunity to combine in-depth work in theory with work in broadly defined “applied” or “functional” areas, with faculty held to be experts in their fields.

A candidate entering with a bachelor’s degree should be able to complete the program in four or five years. The first year is devoted to work in the basic disciplines of management and to preliminary work in the student’s major and minor fields. The second year is primarily devoted to the major and minor fields. Finally, two or three years are required for the doctoral dissertation.

Major and Minor Fields

Candidates must master the literature, theory, and application of a major field of concentration as well as a minor field. Successful completion of this requirement is determined by General Examinations. The major fields currently available in the MIT Sloan School are the following (although individually constructed majors are possible):

- Accounting and Control
- Financial Economics
- Information Technologies
- Institute for Work and Employment Research
- Technology, Innovation and Entrepreneurship
- Marketing
- Operations Management
- Organization Studies Group
- Strategy and International Management
- System Dynamics

PhD candidates enter the program with a clear idea in mind of a major field of concentration. An appropriate minor field is then selected—typically a theoretical discipline that provides a foundation for research in the major field. Major fields such as accounting or marketing usually have economics as a minor field, while the organizational studies group has behavioral science.

The subject requirements for the major and minor fields are not rigid. There are normal groups of subjects for the standard fields, but substitutions of other subjects and independent study are possible. Regardless of the major and minor fields chosen, a plan of study designed to prepare the student for General Examinations is worked out by the student and his or her faculty advisor(s).

The General Examinations normally are taken at the end of the second year or beginning of the third year of study, after completion of major and minor field coursework and a research paper (see below). The exact form of general exams varies and may involve written examinations, critiques of research papers, or review papers on prescribed topics. In all cases, the last stage is an oral examination.

The MIT Sloan School is committed to research, and the philosophy and structure of the PhD program reflect this professional commitment. There are two separate research requirements: the second-year research paper and the thesis.

A substantial part of the student’s work in the latter half of the first year and in the second year is devoted to an independent research
project. The topic, design, and execution of the project are left to the student, while advice and criticism are provided by a research advisor and other interested faculty. Upon completion of the project, the student prepares a document that is referred to as the “second-year paper.”

The PhD dissertation consists of significant scholarly research in some area of management. Close working relationships with faculty are established early so that the thesis can be defined as a manageable project as early as possible. Candidates typically require two or three years of full-time work to complete their theses.

There is no language requirement in the MIT Sloan School's PhD program, although in some cases the student and his or her advisor decide that further study of a foreign language is necessary if the student is to work effectively in his or her major field. This is usually true, for example, in the field of Strategy and International Management.

Teaching and Research Assistantships
All doctoral students in the MIT Sloan School are eligible to apply for the approximately 100 part-time research and teaching assistantships available each year.

Inquiries
MBA brochures and application information are available online at http://mitsloan.mit.edu/mba/; questions may be directed to mbaadmissions@sloan.mit.edu. For doctoral information, contact the Doctoral Program Office, Room E60-236, MIT Sloan School of Management, 30 Memorial Drive, Cambridge, MA 02139, phone 617-253-7188 or 617-253-8957. For Leaders for Manufacturing Program brochures, call 617-253-1055. Applications are available at http://mitsloan.mit.edu/.

MASTER'S DEGREE PROGRAM FOR MID-CAREER EXECUTIVES

MIT Sloan Fellows Program in Innovation and Global Leadership
The MIT Sloan Fellows Program in Innovation and Global Leadership is a highly selective, corporate sponsored degree program that brings together 100 mid-career men and women from a wide variety of for-profit and nonprofit industries, organizations, and functional areas. The program is characterized by a rigorous academic curriculum, frequent interactions with international business and government leaders, and a valuable exchange of global perspectives. The fellows work together in a team environment tackling practical issues with a spirit of intellectual adventure. After collaborating across disciplines, cultures, and backgrounds in this intense learning environment, they leave the program with the skills necessary to create change, build alliances, and drive global ventures.

In addition to the traditional 12-month, full-time program, MIT Sloan has introduced the flex option, designed especially for those within a one-hour radius of Boston. The flex option permits fellows to complete the program in two years, after attending the summer term full time, thus allowing them to maintain a presence in their organization.

For more information about the MIT Sloan Fellows Program in Innovation and Global Leadership and how to apply, visit http://mitsloan.mit.edu/fellows/ or contact the program office at MIT Sloan School of Management, 50 Memorial Drive, Suite E52-126, Cambridge, MA 02142-1347, 617-253-8600, fax 617-252-1200, fellows@sloan.mit.edu.

OTHER PROGRAMS

Computation for Design and Optimization
The Computation for Design and Optimization (CDO) master's degree program is available to graduate students interested in the analysis and application of computational approaches to designing and operating engineered systems. The curriculum is designed with a common core that serves all engineering disciplines, and an elective component that focuses on particular applications. Current MIT graduate students can pursue a CDO master’s degree in conjunction with their departmental master’s or doctoral studies. For further information, see the full program description in the Interdisciplinary Graduate Programs section in Part 2, or visit http://web.mit.edu/cdo-program/index.html.

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<th>Name</th>
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<tr>
<td>Steven D. Eppinger, ScD</td>
<td>General Motors Leaders for Manufacturing Professor of Management</td>
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<td>William F. Pounds Professor of Management (On leave)</td>
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Richard Dunlop Robinson, PhD

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Edgar H. Schein, PhD

Professor of Management, Emeritus
Above all, science is elegant, beautiful, and mysterious; it ennobles the human spirit. It is a privilege—whether for a semester, four years, or a lifetime—to attempt to understand nature at its most fundamental level. In the School of Science, research and education are inextricably interwoven, and our faculty is committed to excellence in both endeavors.
Much of MIT's uniqueness and great success rests on the fact that research and education in the sciences are at the core of the Institute. Thus, every undergraduate student at MIT learns the basic elements of chemistry, mathematics, physics, and molecular biology. The School of Science offers frontier research and educational programs in virtually all areas of contemporary science.

Science at MIT is simultaneously very abstract and very practical. Most importantly, it is always exciting. An education in science, both at the undergraduate and at the graduate level, prepares one for many careers. Students with bachelor's degrees in science often go on to medical school, law school, business school, and other professional schools including engineering. Some, of course, also go on to pursue PhDs in their fields of specialization. Many students with PhD degrees in science or mathematics pursue distinguished careers in research and education. However, others enjoy equally satisfying careers in business, industry, and government. Many combine their PhD degrees in science with medical, law, or business degrees and are uniquely prepared to face the modern world.

New Directions
The future for science at MIT is as vast as the creative imaginations of each faculty and student, which continually mandate new academic and research directions for the School. Interests extend from the fundamental constituents of matter such as quarks and gluons to the mysteries of dark matter and dark energy, from the flow of fluids in porous rocks to the flow of currents in the oceans and the atmosphere, from the molecular biology of individual neurons in the brain to the complex processes involved in language acquisition, from the mathematics underlying computer science to the fundamentals of geometry, from the chemistry of catalysis to the biochemical processes involved in photosynthesis, from the microscopic structures of individual proteins to the genetics of cancer.

Students at all levels and of all persuasions are invited to join in this exciting enterprise, as undergraduates or as graduates, as minors or as majors, as generalists or as specialists.

History
Science has been at the core of an MIT education since the Institute's founding by the distinguished natural scientist, William Barton Rogers, in 1861. The earliest offerings in chemistry, geology, and general science were expanded in the 1930s to include physics, mathematics, and biology, under the leadership of Karl Taylor Compton. During his tenure and into the post-war years, the Institute saw vast growth in the physical sciences, as federal funding for basic research increased.

Life sciences attained new prominence in the 1970s and 1980s, and the Department of Biology expanded with the additions of the Center for Cancer Research and the Whitehead Institute for Biomedical Research. Recently, the Department of Brain and Cognitive Sciences expanded with the addition of the Picower Institute for Learning and Memory and the McGovern Institute for Brain Research, adding to the increased School-wide interest in the neurosciences. Today, the sciences at MIT are ranked among the best in the world, a ranking which is reflected in the number of Nobel laureates on the faculty (currently eight) and among alumni of the School.

Interdepartmental Programs
The interdepartmental research centers and laboratories associated with the School of Science include:

- Center for Cancer Research
- Experimental Study Group
- Laboratory for Nuclear Science
- MIT Kavli Institute for Astrophysics and Space Research
- Picower Institute for Learning and Memory
- Spectroscopy Laboratory

Refer to the section on Interdisciplinary Research and Study in Part 1 for detailed descriptions of these centers and labs. For a description of the Radiological Sciences Joint Doctoral Program, refer to the Harvard-MIT Division of Health Sciences and Technology section under Interdisciplinary Graduate Programs in Part 2.

Computational and Systems Biology
The emerging field of computational and systems biology represents an integration of concepts and ideas from the biological sciences, engineering disciplines, and computer science. Recent advances in biology, including the human genome project and massively parallel approaches to probing biological samples, have created a new opportunity to focus on understanding biological problems from a systems perspective. Systems modeling and design are well established in engineering disciplines but are relatively new to biology. Advances in computational and systems biology require multidisciplinary teams with skill in applying principles and tools from engineering and computer science to solve problems in biology and medicine. To provide education in this emerging field, the Computational and Systems Biology (CSB) program integrates MIT's world-renowned disciplines in biology, engineering, math and computer science. Graduates of the program will be uniquely prepared to develop new methods, make novel discoveries and establish new paradigms. They will also be well positioned to assume critical leadership roles in both academia and industry, where this new area is becoming increasingly important.

For more information on the CSB program, see the Interdisciplinary Graduate Programs section in Part 2.

Publications
Brochures which describe the academic programs and research centers are available through each department; contact the appropriate academic officer directly.
### Degrees Offered in the School of Science

#### Biology  Course 7
- **SB** Biology
- **PhD** Biochemistry
- **PhD** Biological Oceanography (jointly offered with WHOI)
- **PhD** Biophysical Chemistry and Molecular Structure
- **PhD** Cell Biology
- **PhD** Developmental Biology
- **PhD** Genetics/Microbiology
- **PhD** Immunology
- **PhD** Neurobiology

#### Brain and Cognitive Sciences  Course 9
- **SB** Brain and Cognitive Sciences
- **PhD** Cognitive Science
- **PhD** Neuroscience

#### Chemistry  Course 5
- **SB** Chemistry
- **PhD, ScD** Biological Chemistry
- **PhD, ScD** Inorganic Chemistry
- **PhD, ScD** Organic Chemistry
- **PhD, ScD** Physical Chemistry

#### Computational and Systems Biology  Course CSB
- **PhD** Computational and Systems Biology (jointly offered with the School of Engineering)\(^6\)

#### Earth, Atmospheric, and Planetary Sciences  Course 12
- **SB** Earth, Atmospheric, and Planetary Sciences
- **SM** Atmospheric Science
- **SM** Earth and Planetary Sciences
- **SM** Geosystems
- **SM** Marine Geology and Geophysics (jointly offered with WHOI)
- **SM** Oceanography (jointly offered with WHOI)
- **PhD, ScD** Atmospheric Chemistry
- **PhD, ScD** Atmospheric Science
- **PhD, ScD** Climate Physics and Chemistry
- **PhD, ScD** Geochemistry
- **PhD, ScD** Geology
- **PhD, ScD** Geophysics
- **PhD, ScD** Physical Oceanography (jointly offered with WHOI)
- **PhD, ScD** Planetary Sciences

#### Mathematics  Course 18
- **SB** Mathematics
- **SB** Mathematics with Computer Science
- **PhD** Mathematics

#### Physics  Course 8
- **SB** Physics
- **SM** Physics
- **PhD** Physics

### Notes
Many departments make it possible for a graduate student to pursue a simultaneous master's degree.

Several departments also offer undesignated degrees, which lead to the Bachelor of Science without departmental designation. The curricula for these programs offer students opportunities to pursue broader programs of study than can be accommodated within a four-year departmental program.

\(^6\) See Interdisciplinary Graduate Programs section in Part 2.

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Assistant to Dean for Administration
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Assistant to Dean for Personnel
The Department of Biology offers undergraduate, graduate, and postdoctoral training in basic biology, and in a variety of biological fields of specialization. The quantitative aspects of biology, including molecular biology, biochemistry, genetics, and cell biology, represent the core of the program. Students in the department are encouraged to acquire a solid background in the physical sciences not only to master the applications of mathematics, physics, and chemistry to biology, but also to develop an integrated scientific perspective. The various programs, which emphasize practical experimentation, combine a minimum of formal laboratory exercises with ample opportunities for research work both in project-oriented laboratory subjects and in the department’s research laboratories. Students at all levels are encouraged to acquire familiarity with advanced research techniques and to participate in seminar activities.

UNDERGRADUATE STUDY

Bachelor of Science in Biology/Course 7
The curriculum leading to the Bachelor of Science in Biology is designed to prepare students for a professional career in the area of the biological sciences. Graduates of this program are well prepared for positions in industrial or research institutes. However, experience has shown that many graduates choose to continue their education at a graduate school in order to obtain a PhD in an area such as biochemistry, microbiology, genetics, biophysics, cell biology, or physiology, followed by research or teaching in one of those areas. The undergraduate curriculum is also excellent preparation for students who wish to continue their education toward an MD, particularly if their career plans include laboratory investigations bearing on human disease.

Bachelor of Science as Recommended by the Department of Biology/Course 7-A
Course 7-A is designed for students who wish to obtain a background in biology as preparation for careers without laboratory research. Course 7-A has the same requirements as Course 7, and requires 180 units beyond the GIs, except that it does not require a 30-unit laboratory subject. To satisfy the requirement that students complete two Communication Intensive subjects in the major, students must take 7.02 and one subject from this list of approved CI-M subjects for Course 7-A: 3.014, 3.042, 5.32, 5.33, 7.19, 8.13, 9.02, 9.12, 9.18, 9.63, 10.26, 10.28, 10.29, or 2.791/6.021/20.370. Further details on the 7-A major and CI-M subjects may be obtained from the department.

Additional information regarding undergraduate academic programs, research opportunities, admissions, and financial aid may be obtained from the Biology Education Office, Room 68-120, MIT, 617-253-4718, undergradbio@mit.edu.

Students should use their elective subjects for more advanced subjects in their field and for additional study in basic and advanced subjects offered in various departments.

Minor Program in Biology
The requirements for a Minor in Biology are as follows:

- 5.12 Organic Chemistry I
- 7.03 Genetics
- 7.05 General Biochemistry
- Two additional subjects from: 7.02, 7.06, 7.08, 7.20, 7.21, 7.22, 7.23, 7.24, 7.25, 7.27, 7.28, 7.29, 7.31, 7.35, 7.36, and 7.37.

For a general description of the minor program, see Undergraduate Education in Part 1.

GRADUATE STUDY

The Department of Biology offers graduate work leading to the Doctor of Philosophy. Study may be pursued in the following fields of specialization.

Biochemistry is the study of enzyme catalysis, and the chemical properties of proteins, carbohydrates, complex lipids, nucleic acids, and protein-nucleic acid complexes. Methods of analysis include gene cloning, the use of genetic variants, synthetic substrates, and transition state analogs. Specific areas of study include the chemistry of oncogenes, mechanism of RNA splicing, analysis of cytoskeletal proteins, chemistry of blood coagulation, mechanism of ion pumps and photoreceptors, and the role of complex carbohydrates in cell surface function and protein compartmentalization.

Biophysical chemistry and molecular structure focuses on studies of the principles that underlie the folding, stability, molecular design, and assembly of proteins and nucleic acids. Analysis of molecular structure includes X-ray crystallography and Nuclear Magnetic Resonance. Specific areas of concentration include the study of genetic strategies for enhancing the stability, ligand affinity, and catalytic efficiency of proteins and enzymes; pathways of protein folding; protein-nucleic acid recognition; and antigen-antibody interactions. Studies of more complex systems include the control of viral and cytoskeletal assembly.

Cell biology refers to molecular biological, genetic, and cell biological analysis of eukaryotic cells. The specific areas of research include the organization, expression, and regulation of eukaryotic genomes; structure and function of membranes and cytoskeletons; molecular basis of cellular structure, organization, proliferation, and movement; differentiation and functions of specialized cell types; and the molecular basis of various diseases.

Computational and systems biology is a very recent area of emphasis in the department that is being co-developed with the Department of Electrical Engineering and Computer Science and the Division of Biological Engineering as part of the Computational and Systems Biology Initiative (CSBi). Computational and systems biology combines biology, engineering, and computer science in a multi-disciplinary approach to the systematic analysis of complex biological phenomena. Equal emphasis is placed on computational and experimental research and on molecular and systematic views of biological function. One major role of CSBi research is to develop methods and devices that can measure, in a systematic and precise manner, the biochemical properties of large numbers of biomolecules in cells, tissues, and whole organisms. A second major CSBi goal is to build mathematical models of biological systems that link mechanistic understanding of molecular function to systems-wide knowledge of networks and interactions. Like models in mature engineering disciplines, CSBi models will capture empirical knowledge as it accumulates and will have the ability to predict experimental outcomes.

Developmental biology refers to the cellular, genetic, and molecular mechanisms responsible
Bachelor of Science in Biology/Course 7

General Institute Requirements (GIRs)  
Subjects  
Science Requirement [two subjects can be satisfied by 5.111 or 5.112 or 3.091 and 7.012 or 7.013 or 7.014 in the Departmental Program]  6  
Humanities, Arts, and Social Sciences Requirement  8  
Restricted Electives in Science and Technology (REST) Requirement [can be satisfied from among 5.12, 5.60, and 7.03 or 7.05 in the Departmental Program]  2  
Laboratory Requirement [can be satisfied by 7.02 in the Departmental Program]  1  
Total GIR Subjects Required for SB Degree  17  

Communication Requirement  
The program includes a Communication Requirement of 4 subjects:  
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and  
2 subjects designated as Communication Intensive in the Major (CI-M).  

PLUS Departmental Program  
Subjects below are followed by credit units, and by prerequisites if any (corequisites are indicated in italics)  
Units  
Required Subjects  102  
5.111/5.112 Principles of Chemical Science, 12  
or  
3.091 Introduction to Solid-State Chemistry, 12  
5.12 Organic Chemistry I, 12, REST; 5.111*  
5.60 Thermodynamics and Kinetics, 12, REST; 18.02, 5.111*  
or  
20.110j Thermodynamics of Biomolecular Systems, 12; 18.02; 5.111, 5.112, or 3.091  
7.012 Introductory Biology,10j 12  
or  
7.013 Introductory Biology,10j 12  
or  
7.014 Introductory Biology,10j 12  
7.02/10.702 Introduction to Experimental Biology and Communication, 18, LAB, CI-M; 7.012*  
7.03 Genetics, 12, REST; 7.012*  
7.05 General Biochemistry, 12, REST; 5.12, 7.012*  
or  
5.07 Biological Chemistry I, 12; 5.12  
7.06 Cell Biology, 12; 7.03, 7.05  

Restricted Electives  66  
Three undergraduate-level 12-unit subjects offered by the Department of Biology for which 7.03 and/or 7.05 are prerequisites. Exceptions: 7.30j is eligible as a restricted elective; 7.19 cannot be used as a restricted elective. Graduate-level subjects may not be used as restricted electives. Subjects that count as restricted electives are the following: 7.08j, 7.20j, 7.21, 7.22, 7.23, 7.24, 7.25, 7.27, 7.28, 7.29j, 7.30j, 7.31, 7.35, 7.36, and 7.37j.  
One of the 30-unit project laboratory subjects in the department curriculum. Those currently offered are:  
7.13 Experimental Microbial Genetics, 30, CI-M; 7.02, 7.03, 7.05  
7.16 Experimental Molecular Biology: Biotechnology II, 30, CI-M; 7.02, 7.03, 7.05  
7.17 Experimental Molecular Biology: Biotechnology III, 30, CI-M; 7.02, 7.03, 7.05  
7.18 Topics in Experimental Biology, 30, CI-M; 7.02, 7.03, 7.05  

Departmental Program Units That also Satisfy the GIRs  (66)  
Unrestricted Electives  78  

Total Units Beyond the GIRs Required for SB Degree  180  
No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.  

Notes  
*Alternate prerequisites are listed in the subject description.  
(1) Either 7.02 or 5.311 satisfies the Institute Laboratory Requirement. However, both or their equivalent are required in order to satisfy medical school entrance requirements.  
(2) 7.012/10.702/7.014 are intended to be first biology subjects and are not to be taken after other biology subjects.  
For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
Entrance Requirements for Graduate Study
In the Department of Biology, the Master of Science is not a prerequisite for a program of study leading to the doctorate.

The department modifies the General Institute Requirements for admission to graduate study as follows: 18.01, 18.02 Calculus; one year of college physics; 5.12 Organic Chemistry I; professional subjects including general biochemistry, genetics, and physical chemistry. However, students may make up some deficiencies over the course of their graduate work.

Doctor of Philosophy
The General Institute Requirements for the Doctor of Philosophy are listed under Graduate Education in Part 1. In the departmental program, each graduate student is expected to acquire a solid background in four fundamental areas of biology: biochemistry, genetics, cell biology, and molecular biology. Most students take subjects in these areas during the first year. All students are required to take three subjects: 7.52 Genetics for Graduate Students, 7.51 Principles of Biochemical Analysis, and 7.50 Method and Logic in Molecular Biology. This last subject is a seminar designed specifically to introduce graduate students to in-depth discussion and analysis of topics in molecular biology.

Students also have a choice of several elective subjects, which have been designed for the entering graduate student. In addition to providing a strong formal background in biology, the first-year program serves to familiarize the students with faculty and students in all parts of the department.

Joint Program with the Woods Hole Oceanographic Institution/Course 7-W
MIT and the Woods Hole Oceanographic Institution administer a joint program in biological oceanography leading to a jointly awarded Doctor of Philosophy. The program is described at the end of Part 2.

Financial Support
Students who are accepted into the graduate program are provided with support from departmental training grants, departmental funds for teaching assistants, and research grants. In addition, some students bring NSF and other competitive fellowships. Through these sources, full tuition plus a stipend for living expenses are provided.

Students are encouraged to apply for outside fellowships for which they are eligible, such as the National Science Foundation Fellowships. Information regarding graduate student fellowships is available at most colleges from the career planning office.

Inquiries
Additional information regarding graduate academic programs, research activities, admissions, financial aid, and assistantships may be obtained from the Biology Education Office, Room 68-120, MIT, 617-253-3717, gradbio@mit.edu.

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Mandana Sassanfar, PhD


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The study of mind, brain, and behavior has grown in recent years with unprecedented speed. New avenues of approach, opened by developments in the biological and computer sciences, raise the hope that human beings, who have achieved considerable mastery over the world around them, may also come closer to an understanding of themselves. The goal of the Department of Brain and Cognitive Sciences is to answer fundamental questions concerning intelligent processes and brain organization. To this end, the department focuses on four themes: molecular and cellular neuroscience, systems neuroscience, cognitive science, and computation. Several members of the department’s faculty are affiliated with two major research centers: the Picower Institute for Learning and Memory and the McGovern Institute for Brain Research.

Research in cellular neuroscience deals with the biology of neurons, emphasizing the special properties of these cells as encoders, transmitters, and processors of information. Departmental researchers apply techniques of contemporary molecular and cellular biology to problems of neuronal development, structure, and function, resulting in new understanding of the underlying basic components of the nervous system and their interactions. These studies have profound clinical implications, in part by generating a framework for the treatment of neurological and psychiatric disorders. Primary areas of interest include the development and plasticity of neuronal morphology and connectivity, the cellular and molecular bases of behavior in simple neuronal circuits, neurochemistry, and cellular physiology.

In the area of systems neuroscience, departmental investigators use a number of new approaches ranging from computation through electrophysiology to biophysics. Of major interest are the visual and motor systems where the scientific goals are to understand transduction and encoding of sensory stimuli into nerve messages, organization and development of sensorimotor systems, processing of sensorimotor information, and the sensorimotor performance of organisms. Also of major interest is neural and endocrine regulation, where the scientific goal is to understand the effects of circulating compounds on brain composition and behavior.

In computation and cognitive science, particularly strong interactions exist between the Department of Brain and Cognitive Sciences, the Computer Science and Artificial Intelligence Laboratory, and the Center for Biological and Computational Learning, providing new intellectual approaches in areas including vision and motor control, and biological and computer learning. Computational theories are developed and tested within the framework of neurophysiological, psychological, and other experimental approaches. In the study of vision and motor control, complementary experimental work includes single-cell and multiple-cell neurophysiological recording as well as functional brain imaging. In the area of learning, which is seen as central to intelligent behavior, departmental researchers along with members of the Center for Biological and Computational Learning are working to develop theories of vision, motor control, neural circuitry, and language within an experimental framework.

In cognitive science, human experimentation is combined with formal and computational analyses to understand complex intelligent processes such as language, reasoning, memory, and visual information processing. There are applications in the fields of education, artificial intelligence, human-machine interaction, and in the treatment of language, cognitive, and other disorders.

Subfields in cognitive science include psycholinguistics, comprising sentence and word processing, language acquisition, and aphasia; visual cognition, including reading, imagery, attention, and perception of complex patterns such as faces, objects, and scenes; spatial cognition; memory; and the nature and development of concepts. Another key field is the study of perception—developmental and processing approaches focus on human and machine vision, and how visual images are encoded, stored, and retrieved, with current topics that include motion analysis, stereopsis, perceptual organization, and perceptual similarity. Other research includes functional brain imaging in normal subjects as well as studies of neurologically impaired patients in an attempt to understand brain mechanisms underlying normal human sensation, perception, cognition, action, and affect.

**UNDERGRADUATE STUDY**

**Bachelor of Science in Brain and Cognitive Sciences/Course 9**

Brain science and cognitive science are complementary and interactive in their research objectives. Both approaches examine perception, performance, and intervening processes in humans and animals. Central issues in the discipline include the interpretation of sensory experience; the reception, manipulation, storage, and retrieval of information within the nervous system; and the planning and execution of motor activity. Higher level functions include the development of formal and information reasoning skills; and the structure, acquisition, use, and internal representation of human language.

The Bachelor of Science in Brain and Cognitive Sciences prepares students for graduate training in neurosciences, medicine, cognitive science, psychology, linguistics, philosophy, or aspects of artificial intelligence (particularly those aspects concerned with vision) as well as for further work in the area of efficient human-machine interaction.

Methods of inquiry in the brain and cognitive sciences are drawn from molecular, cellular, and systems neuroscience; cognitive and perceptual psychology; computer science and artificial intelligence; linguistics; philosophy of language and mind; and mathematics. The undergraduate program is designed to provide instruction in the relevant aspects of these various disciplines. The program is administered by an Undergraduate Officer and an Undergraduate Assistant, consulting as necessary with faculty members from these disciplines who also serve as advisors to majors, helping them select a coherent set of subjects from within the requirements, including a research requirement. Members of the faculty are available to guide the research.

**Minor Program in Brain and Cognitive Sciences**

The Minor in Brain and Cognitive Sciences consists of six subjects arranged in two tiers of study, intended to provide students breadth in the field as a whole and some depth in one of two areas of specialization.
 Bachelor of Science in Brain and Cognitive Sciences/Course 9

General Institute Requirements (GIRs)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement (three subjects can be satisfied by 9.00 and two other HASS subjects in the Departmental Program)</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement (one subject can be satisfied by 9.01 in the Departmental Program)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement (can be satisfied by a laboratory in the Departmental Program)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

Communication Requirement

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Subjects</td>
<td></td>
<td>126–132</td>
</tr>
<tr>
<td>9.00 Introduction to Psychology, 12, HASS</td>
<td></td>
<td></td>
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<tr>
<td>9.01 Introduction to Neuroscience, 12, REST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.07 Statistics for Brain and Cognitive Sciences, 12; 18.01, 18.02*</td>
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<tr>
<td>or 6.041, 14.30, 18.05, 18.440 or any of the following Harvard courses: Statistics 100, 101, or 102 may be used to fulfill the statistics requirement</td>
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</tr>
<tr>
<td>Core Subjects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choose six subjects from three areas: cognitive science, cognitive neuroscience, and neuroscience. Any combination of subjects is permitted, but at least one subject must be chosen in a second area.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cognitive Science

- Perceptual, Knowledge, and Cognition, 9; 9.00*
- Anigrafs, 12; 9.34*
- Abnormal Language, 12; 24.900*
- Language Acquisition, 12, HASS; 24.900*
- Psycholinguistics, 12, HASS; 9.00, 24.900*
- Cognitive Processes, 12, HASS; 9.00
- Computational Cognitive Science, 12; 9.00; 9.05; 18.05, or 6.042*
- Infant and Early Childhood Cognition, 12; 9.00
- Introduction to Linguistics, 12, CI-H

Cognitive Neuroscience

- Cognitive Neuroscience, 12; 9.01
- Animal Behavior, 12, HASS; 9.00*
- A Clinical Approach to the Human Brain, 12
- Sensation and Perception, 12; 8.02, 18.02*
- Functional MRI of High-Level Vision, 12; 9.07; 9.34, 9.35, 9.64, or 9.66*

Neuroscience

- Neural Basis of Learning and Memory, 12; 9.01
- Neural Basis of Vision and Audition, 12; 9.01*
- Neural Basis of Movement, 12; 9.01*
- Cellular Neurobiology, 12; 7.05
- Brain Structure and Its Origins, 12; 9.01
- Biochemistry and Pharmacology of Synaptic Transmission, 12; 9.01, 7.05*
- Cellular Neurophysiology, 12; 9.01, 9.09)*
- Developmental Neurobiology, 12; 9.01, 7.03, 7.05*
- Diseases of the Nervous System, 12; 9.01
- Introduction to Computational Neuroscience, 12; 18.03, 8.02*

Laboratory

One of the following is required:

- Brain Laboratory, 12, LAB, CI-M; 9.01
- Experimental Molecular Neurobiology, 12, LAB, CI-M, 7.012*
- Laboratory in Cognitive Science, 12, LAB, CI-M
For a listing of available subjects in these areas, consult the HASS Office, Room 14N-408 or the BCS Undergraduate Office, Room 46-2005, 617-253-0482.

No more than three of the subjects used to satisfy the requirements for the major in brain and cognitive sciences may be used for the minor (or concentration) in psychology.

For a general description of the minor program, see Undergraduate Education in Part 1.

GRADUATE STUDY

The Department of Brain and Cognitive Sciences offers programs of study leading to the doctoral degree in neuroscience or cognitive science. Areas of research specialization include cellular and molecular neuroscience, systems neuroscience, computation, and cognitive science. The graduate programs are designed to prepare participants to teach and to do original research.

Doctor of Philosophy

The departmental PhD program can normally be completed with four or five years of full-time work, including summers. Institute requirements for the PhD are given in the section on General Degree Requirements in Part 1. Formal coursework, described below, is intended to prepare the student to pass the general examinations and do original thesis research. The written general examinations will be given in June of the second year.

All students start with a first-term intensive core subject that provides an introduction to brain and behavioral studies from the viewpoint of systems neuroscience. In the spring term, students may choose between two core subjects, one covering cellular/molecular neuroscience and one covering cognitive science. Incoming graduate students are encouraged to take all three within the first two years of study. Further coursework will be diversified to give each individual the appropriate background for research in his or her own area.

Coursework in cellular and molecular neuroscience emphasizes the current genetic, molecular, and cellular approaches to biological systems that are necessary to generate advances in neuroscience.

Training in systems neuroscience covers neuroanatomy, neurophysiology, and neurotransmitter chemistry, concentrating on the major sensory and motor systems in the vertebrate brain. Specific ties to molecular neurobiology or computation may be emphasized, depending upon the research interests of the student.

Coursework for students in computation is intended to give both an understanding of empirical approaches to the study of the vertebrate brain and animal behavior and a theoretical background for analyzing computational aspects of biological information processing.

Candidates studying cognitive science take coursework covering such topics as language processing, language acquisition, cognitive development, natural computation, neural networks, connectionist models, and visual information processing. Students also choose seminars and coursework in linguistics, philosophy, logic, mathematics, or computer science, depending on the individual student's research program.

Graduate students begin a research apprenticeship immediately upon arrival with lab rotations in the first year, after which time advisor assignments are made based upon a match of interests. These assignments may change as a student's goals become more focused. At the end of the first year, an advisory committee of two to four faculty members is formed. This committee monitors progress and, with membership changing as necessary, evolves into the thesis committee. Thesis research normally requires 24–36 months of full-time activity after the qualifying examinations have been passed. It is expected that the research embodied in the PhD dissertation be original and significant work, publishable in scientific journals.

Assistantships and Fellowships

Financial assistance is provided to qualified applicants in the form of traineeships, research assistantships, teaching assistantships, and a limited number of fellowships, subject to availability of funds. Prospective students are encouraged to apply for individual fellowships such as those sponsored by the National Science Foundation and the National Defense Science and Engineering Graduate Fellowship Program to cover all or part of the cost of their education. The department's financial resources for non-US citizens are limited; international students are strongly encouraged to seek financial assistance for all or part of the cost of their education from non-MIT sources.

Inquiries

For additional information regarding teaching and research programs, contact the Graduate Office, Department of Brain and Cognitive Sciences, Room 46-2005, MIT, 617-253-7403, or visit http://web.mit.edu/bcs/.
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Ken-ichi Amemori, PhD
Christopher Baker, PhD
Anna Bolteus, PhD
Miguel Bosch Pita, PhD
Scott Louis Brincat, PhD
Mehmet Cansev, MD
Christie Chung, PhD
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Ivana Delalle, PhD
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Antonia Diogo, PhD
George Dragoi, PhD
Dieter Edbauer, PhD
Valerie Ego-Stengel, PhD
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Tadahiro Fujino, MD, PhD
Kensuke Futai, PhD
Nadine Gaab, PhD
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Joanne Gibson, PhD
Jodel Giraud, PhD
Jesse Goldberg, PhD
Stephen Gomperts, PhD
Noah Goodman, PhD
Zhuo Guan, PhD
Shlomit Hanz, PhD
Mansuo Hayashi, PhD
Mariko Hayashi, PhD
Mark Histed, PhD
Natasha Hussain, PhD
Beata Jarosiewicz, PhD
Daoyun Ji, PhD
Ariel Kamsler, PhD
Wolfgang Kelsch, PhD
Myung Jung Kim, PhD
Fabian Kloosterman, PhD
Konrad Koerding, PhD
Keigo Kohara, PhD
Byung-Hoon Lee, PhD
Hysong Lee, PhD
Zheng Li, PhD
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Zuxiang Liu, PhD
Jonathan Loewenstein, PhD
Michael Long, PhD
Sanjay Magavi, PhD
Rong Mao, PhD
Yingwei Mao, PhD
Alan Marrett, PhD
David McMahon, PhD
Ming Meng, PhD
Amanda Mower, PhD
Lily Moy, PhD
Yasunobu Murata, PhD
Joseph Murray, PhD
Toshiaiki Nakashiba, PhD
Radhakrishnan Narayanan, PhD
Kevin Neville, PhD
Yoshiiha Ninokura, PhD

**Visiting Scientists/Scholars**
Sumantra Chattarji, PhD
Yuri Ivanov, PhD
Minho Lee, PhD
Kenway Louie, PhD
Stephan Niemann, PhD
Junghup Suh, PhD
Sujith Vijayan, PhD

**Professor Emeritus**
Richard Held, PhD
Professor of Experimental Psychology, Emeritus
Chemistry is the study of the nanoworld, the world of atoms and molecules spanning dimensions from one to several thousand angstroms. Chemists study the architecture of this miniature universe, explore the changes that occur, unravel the principles that govern these chemical changes, and devise ways to create entirely new compounds and materials. Past triumphs of chemistry include the synthesis of pharmaceuticals and agricultural products, while current challenges include chemical memory, solar cells, superconductors, and the solution of numerous important problems relating to health and the environment.

The Department of Chemistry offers the Bachelor of Science, Doctor of Philosophy, and Doctor of Science degrees. The department’s program of teaching and research spans the breadth of chemistry. General areas covered include biological chemistry, inorganic chemistry, organic chemistry, and physical chemistry. Some of the research activities of the department are carried out in association with the work of interdisciplinary laboratories and centers (see Part 1) such as the Center for Materials Science and Engineering, the Francis Bitter Magnet Laboratory, the Harvard-MIT Division of Health Sciences and Technology, the Institute for Soldier Nanotechnologies, the Laboratory for Energy and the Environment, the Lincoln Laboratory, and the Spectroscopy Laboratory.

The undergraduate program aims to provide rigorous education in the fundamental areas of chemical and biochemical knowledge and experimentation. Undergraduate students are encouraged to involve themselves in the Undergraduate Research Opportunities Program (UROP) and to take graduate-level chemistry classes as well as subjects in other departments at the Institute, Harvard, or Wellesley.

The Department of Chemistry graduate program admits applicants for the Doctor of Philosophy and the Doctor of Science degrees. In addition to formal coursework, each student undertakes a research problem that forms the core of graduate work. Graduate and postgraduate level research is often carried out in collaboration with scientists in other faculties and interdisciplinary laboratories.

For more information, see [http://web.mit.edu/chemistry/www/](http://web.mit.edu/chemistry/www/).

### Undergraduate Study

#### Bachelor of Science in Chemistry/ Course 5

The Department of Chemistry offers an undergraduate program sufficiently flexible in its electives to provide excellent preparation for careers in many different areas of chemistry. Course 5 is designed to provide an education based on science both for those who intend to go on to graduate study and for those who intend immediately to pursue a professional career in either chemistry or an allied field in which a sound knowledge of chemistry is important. Students receive thorough instruction in the principles of chemistry, supplemented by a strong foundation in mathematics, physics, biology, and the humanities. A Certification in Biochemistry by the American Chemical Society can be received with a bachelor’s degree for students interested in concentrating in this area. The Department of Chemistry also teaches courses jointly with the departments of Biology and Chemical Engineering, and with the Biological Engineering Division.

Unrestricted elective time allows students to extend their knowledge in areas of special interest. Those intending to do graduate work may elect subjects in the department or in other departments that give them more detailed knowledge in the areas in which they wish to specialize. Students who plan to enter industry may elect subjects that offer the fundamentals in a selected field of science, engineering, or the humanities and social sciences. Programs may also be elected that lead to simultaneous Bachelor of Science degrees in two fields of specialization.

The student’s faculty advisor can offer suggestions for elective subjects that are of value in preparation for specialization in the various broad areas of chemistry. The proper choice of electives is particularly important for students planning to continue their education in a graduate school.

Students at all levels are encouraged to undertake original research under the supervision of a member of the chemistry faculty, and students carrying out research over at least three terms have the option of preparing an undergraduate thesis.

### Minor Program in Chemistry

The requirements for a Minor in Chemistry are as follows:

- 5.03 Principles of Inorganic Chemistry I
- 5.12 Organic Chemistry I
- 5.310 Laboratory Chemistry
- 5.60 Thermodynamics and Kinetics

Two additional subjects from the following:

- 5.04 Principles of Inorganic Chemistry II
- 5.07 Biological Chemistry I
- 5.08 Biological Chemistry II
- 5.13 Organic Chemistry II
- 5.32 Intermediate Chemical Experimentation
- 5.43 Advanced Organic Chemistry
- 5.61 Physical Chemistry
- 5.62 Physical Chemistry

For a general description of the minor program, see Undergraduate Education in Part 1.

### Inquiries

Additional information may be obtained from the Chemistry Department, Chemistry Education Office, Room 2-204, MIT, 617-253-7271.

### Graduate Study

The Department of Chemistry offers the Doctor of Philosophy and Doctor of Science degrees. The subjects offered for these degrees aim to develop a sound knowledge of fundamentals and a familiarity with current progress in the most active and important areas of chemistry. In addition to studying formal subjects, each student undertakes a research problem that forms the core of graduate work. Through the experience of conducting an investigation leading to the doctoral thesis, a student learns general methods of approach and acquires training in some of the specialized techniques of research.

The areas of research in the department include organic, inorganic, physical, and biological chemistry. The thesis frequently involves more than one of these fields. Some of the research activities of the department are carried out in association with the work of interdisciplinary laboratories and centers such as the Center for Materials Science and Engineering, the Francis Bitter Magnet Laboratory, the Harvard-MIT Division of Health Sciences and Technology, the Institute for Soldier Nanotechnologies, the Laboratory for Energy and the Environment, the Lincoln Laboratory, and the Spectroscopy Laboratory.
Part 2
School of Science

for Materials Science and Engineering and the Spectroscopy Laboratory, described in the section on Interdisciplinary Research and Study in Part 1. These interdisciplinary research laboratories provide stimulating interaction among the research programs of several MIT departments and give students the opportunity to become familiar with research work in disciplines other than chemistry. Detailed information on the research activities of the faculty can be found in the Directory of Graduate Research published by the American Chemical Society. Detailed information can be found on the departmental website, http://web.mit.edu/chemistry/www/.

During the first term of residence, all graduate students are encouraged to select research supervisors who serve as advisors for the balance of their graduate careers. In particular, the overall program of graduate subjects is established by each student and the research supervisor. In planning this program and in establishing the thesis problem, careful consideration is given to the candidate’s academic record and professional experience, as well as to long-range objectives.

Entrance Requirements for Graduate Study

Students intending to pursue graduate work in the Chemistry Department should have excellent undergraduate preparation in chemistry. The department, however, is flexible with respect to the specific mathematics and physics preparation; the essential requirement is demonstration of ability to progress with advanced study and research in some area of special interest.

Mathematics and physics are important prerequisites for graduate work in physical chemistry or chemical physics, whereas less preparation in these areas is required for work in organic chemistry.

Applicants to the Chemistry Department are requested to submit scores from the verbal and quantitative sections of the Graduate Record Examination. Scores on the advanced examinations are optional.

Bachelor of Science in Chemistry/Course 5

General Institute Requirements (GIRs)

Science Requirement (one subject can be satisfied by 5.111 or 5.112 in the Departmental Program) 6
Humanities, Arts, and Social Sciences Requirement 8
Restricted Electives in Science and Technology (REST) Requirement (one subject can be satisfied by 5.12, 5.60, or 5.61 in the Departmental Program) 2
Laboratory Requirement (can be satisfied by 5.311 in the Departmental Program) 1
Total GIR Subjects Required for SB Degree 17

Communication Requirement
The program includes a Communication Requirement of 4 subjects:
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics).

Required Subjects 132
5.03 Principles of Inorganic Chemistry I, 12; 5.12
5.07 Biological Chemistry I, 12; 5.12
5.111 or 5.112 Principles of Chemical Science(1), 12
5.12 Organic Chemistry I, 12, REST; 5.111*
5.13 Organic Chemistry II, 12; 5.12
5.32 Introductory Chemical Experimentation, 12, LAB; 5.12
5.33 Intermediate Chemical Experimentation, 15, CI-M; 5.311*, 5.12, 5.60
5.33 Advanced Chemical Experimentation and Instrumentation, 21, CI-M; 5.32, 5.61
5.60 Thermodynamics and Kinetics, 12, REST; 18.02, 5.111*
5.61 Physical Chemistry, 12, REST; 8.02, 18.02, 5.111*

Restricted Electives 24
At least two of the following four subjects:
5.04 Principles of Inorganic Chemistry II, 12; 5.03
5.08 Biological Chemistry II, 12; 5.12, 5.07 or 7.05
5.43 Advanced Organic Chemistry, 12; 5.13
5.62 Physical Chemistry, 12; 5.60, 5.61

Departmental Program Units That also Satisfy the GIRs (36)(1)

Unrestricted Electives 60

Total Units Beyond the GIRs Required for SB Degree 180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

Notes
*Alternate prerequisites are listed in the subject description.
(1) Students who do not take 5.111 or 5.112 to fulfill the General Institute Requirement in Chemistry will have 24 units in the Departmental Program that will also satisfy the General Institute Requirements.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

(1) Students who do not take 5.111 or 5.112 to fulfill the General Institute Requirement in Chemistry will have 24 units in the Departmental Program that will also satisfy the General Institute Requirements.
Doctor of Philosophy and Doctor of Science

The Chemistry Department does not have any formal subject requirements for the doctoral degree. Each student, with the advice of a research supervisor, pursues an individual program of study that is pertinent to long-range research interests.

Written major examinations are cumulative. Separate examinations in biological, inorganic, organic, and physical chemistry are offered each month from October through May. The examinations demonstrate an understanding of the important principles of each field. Six cumulative examinations must be passed to complete the written major examination. No fixed time limit is set for completion of this requirement; however, progress is reviewed periodically. No other general written examinations are required. In particular, no qualifying or entrance examinations are given.

A comprehensive oral examination in the candidate’s major field of advanced study is held generally in the fourth term of residence. Progress in the student’s research is also examined at that time. A final oral presentation on the subject of the doctoral research is scheduled after the thesis has been submitted and evaluated by a committee of examiners.

Teaching and Research Assistantships

The department appoints a number of degree candidates as teaching assistants who are assigned either to laboratory subjects or to discussion sections of lecture subjects. Many students receive appointments to research assistantships after their first year, and departmental fellowships are also available. Financial support after the first academic year is subject to the availability of funds and provided for students who maintain a satisfactory record.

Inquiries

Correspondence about the graduate program or appointments should be addressed to the Chemistry Graduate Office, Room 2-204, MIT, 617-253-1845.

FACULTY AND STAFF

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The Department of Earth, Atmospheric, and Planetary Sciences offers the bachelor’s degree in earth, atmospheric, and planetary sciences, and master’s and doctoral degrees in earth and planetary sciences, atmospheric sciences, oceanography, and climate physics and chemistry.

Departmental programs apply physics, chemistry, and mathematics to the study of the Earth and planets in order to understand the processes that are active in the Earth’s interior, oceans, and atmosphere, as well as the interiors and atmospheres of other planets. The department also uses the basic sciences to understand the past history of the Earth and planets. By combining the past history with models of present physical and chemical processes, faculty and students work to develop an understanding of the dynamics of systems as diverse as the global climate system, regional tectonics and deformation, petroleum and geothermal reservoirs, and the solar system.

Department faculty members teach and carry out research through programs in atmospheres, oceans and climate, geochemistry, geology, geobiology, geophysics, and planetary science. Specific research activities include environmental earth science, global climate change science, planetary missions, and earthquake and exploration geophysics.

Modern problems in these fields are approached by field measurements, laboratory studies, and theory. Experimental facilities for training and research are available not only in departmental laboratories such as the Earth Resources Laboratory, but also in MIT’s interdisciplinary laboratories such as the Center for Global Change Science, Kavli Institute for Astrophysics and Space Research, Lincoln Laboratory, Haystack Radio Observatory and Millstone Radar facility, and the Wallace Astrophysical and Geophysical Observatories (described in the section on Interdisciplinary Research and Study), and in cooperating institutions such as the Woods Hole Oceanographic Institution.

UNDERGRADUATE STUDY

Bachelor of Science in Earth, Atmospheric, and Planetary Sciences/ Course 12

The Earth, Atmospheric, and Planetary Sciences Department offers undergraduate preparation for professional careers in a wide range of fields in geoscience (which includes geology, geophysics, and geochemistry), physics of atmospheres and oceans, environmental science, and planetary science and planetary astronomy. Students concentrate in one of these four areas.

The curriculum for the Bachelor of Science in Earth, Atmospheric, and Planetary Sciences ensures a fundamental background through departmental core subjects and advanced study in an area of concentration that includes required subjects and restricted electives. Students are also required to take field and/or laboratory subjects, and to complete an independent research project as part of the degree requirements.

Double-Degree Programs/Five-Year Programs

Studies in physics, chemistry, biology, applied mathematics, and electrical or civil engineering are directly relevant preparation for work in earth, atmospheric, and planetary sciences. Students from these departments can arrange a program of study in Course 12 leading to a second Bachelor of Science in one of the department’s areas of concentration.

Students with strong academic records from the Departments of Earth, Atmospheric, and Planetary Sciences, Chemistry, Physics, Mathematics, Civil and Environmental Engineering, Electrical Engineering and Computer Science, or Chemical Engineering, should be able to complete a Master of Science in Earth and Planetary Sciences, in Atmospheric Sciences, or in Ocean Sciences, or the Master of Science in Geosystems professional degree, in one year of additional study, particularly if programs are arranged for this purpose from the beginning of the fourth year.

The department offers a professional Master’s Degree Program in Geosystems. This intense, quantitative program is open to highly motivated students with undergraduate degrees in geoscience, physics, chemistry, mathematics, or engineering, and can be completed in one academic year. The program prepares students for scientific and management careers in the environmental, natural resources, and technical consulting industries by providing skills in computer simulation and modeling of complex natural systems, as well as scientific inference and data analysis.

Applications for graduate enrollment in the department are considered any time after the beginning of the fourth year. Students may receive the Bachelor of Science as soon as the requirements are completed, or may elect to defer the award for simultaneous presentation with the Master of Science.

Minor Program

The requirements for a Minor in Earth, Atmospheric, and Planetary Sciences are as follows:

Core Subjects

Two subjects from:

- 12.001 Introduction to Geology
- 12.002 Physics and Chemistry of the Solid Earth
- 12.003 Physics of the Atmosphere and Ocean
- 12.004 Introduction to Planetary Science
- 12.006 Nonlinear Dynamics I: Chaos
- 12.102 Environmental Earth Science
- 12.400 The Solar System

One subject from:

- 18.03/18.034 Differential Equations
- 5.60 Thermodynamics and Kinetics

Restricted Electives

Two or more additional Course 12 subjects within one of the EAPS concentration areas, approved by the minor advisor

and 12 units from the following:

- Lab: 12.115, 12.119, 12.307, 12.410
- Field and IAP: 12.120, 12.141, 12.213, 12.214, 12.221, 12.265, 12.310, 12.311, 12.411
- Independent Study: 12.IND, 12.UR

The Earth, Atmospheric, and Planetary Sciences Department jointly offers a Minor in Astronomy with the Department of Physics (Course 8). The description of undergraduate study in Course 8 contains a detailed description and list of requirements for this minor.
Bachelor of Science in Earth, Atmospheric, and Planetary Sciences/Course 12

General Institute Requirements (GIRs)  
Science Requirement Subjects 6  
Humanities, Arts, and Social Sciences Requirement 8  
Restricted Electives in Science and Technology (REST) Requirement [can be satisfied from among 12.001, 12.002, 12.003, 12.004, and 18.03 or 18.034 in the Departmental Program] 2  
Laboratory Requirement 1  
Total GIR Subjects Required for SB Degree 17  

Communication Requirement  
The program includes a Communication Requirement of 4 subjects:  
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and  
2 subjects designated as Communication Intensive in the Major (CI-M).  

PLUS Departmental Program Units  
Required Subjects 114–126  

Introductory Material:  
Two of the following core subjects:  
12.001 Introduction to Geology, 12, REST (required for concentration Area 1 and Area 4 majors)  
12.002 Physics and Chemistry of the Terrestrial Planets, 12, REST; 8.02, 18.02; (required for concentration Area 3 majors)  
12.003 Physics of the Atmosphere and Ocean, 12, REST; 8.01, 18.02; (required for concentration Area 2 and Area 4 majors)  
12.006J Nonlinear Dynamics I: Chaos, 12; 8.02, 18.03  

One of the following mathematics subjects:  
18.03 Differential Equations, 12, REST; 18.02 or 18.014  
18.034 Differential Equations, 12, REST; 18.02 or 18.014  

The following research subject:  
12.TIP Thesis and Independent Study Preparation, 6  

and one of the following:  
12.IND Independent Study (at least 6 units), CI-M; 12.TIP  
12.THU Undergraduate Thesis (at least 6 units), CI-M; 12.TIP (required for concentration Area 3 and Area 4 majors)  

Student must complete one of the following four concentration areas:  
AREA 1 Geoscience  
12.005 Applications of Continuum Mechanics to Earth, Atmospheric, and Planetary Sciences, 12; 8.02, 18.02, 18.03  
12.008 Structure of Earth Materials, 12; 3.091*  
12.113 Structural Geology, 12; 12.001, 12.005  
5.60 Thermodynamics and Kinetics, 12, REST; 18.02, 5.111*  

One of the following sets of field subjects:  
12.221 Field Geophysics, 6  
12.214 Environmental Geophysics, 12; 18.03  
12.222 Field Geophysics Analysis, 6; 12.221, CI-M  

or  

12.114 Field Geology I, 6; 12.108, 12.113*  
12.115 Field Geology II, 18, LAB, CI-M; 12.113, 12.114  

AREA 2 Atmospheres, Oceans, and Climate  
5.60 Thermodynamics and Kinetics, 12, REST; 18.02, 5.111*  
8.03 Physics III, 12, REST; 8.02*, 18.02  
12.330J Fluid Physics, 12; 5.60*  
12.333 Atmospheric and Ocean Circulations, 12; 12.003  

Two of the following physics and mathematics subjects:  
12.008 Classical Mechanics: A Computational Approach, 12; 8.01, 18.03  
8.09 Classical Mechanics II, 12; 8.01  
8.04 Quantum Physics I, 12, REST; 8.03*, 18.03*  
8.07 Electromagnetism II, 12; 8.03, 18.03  
18.311 Principles of Applied Mathematics, 12; 18.03*  

Inquiries  
Additional information may be obtained from the Department of Earth, Atmospheric, and Planetary Sciences, Education Office, Room 54-912, MIT, 617-253-3381.  

GRADUATE STUDY  
The Department of Earth, Atmospheric, and Planetary Sciences offers opportunities for graduate study and research in a wide range of fields, as indicated by the detailed subject descriptions in Part 3. This coursework is the usual prelude to a thesis demonstrating that the student is capable of independent and creative research. A successful thesis leads to a graduate degree: a Master of Science, a Doctor of Philosophy, or a Doctor of Science in the field of specialization.  

A graduate thesis may have either a theoretical, experimental, or observational focus. Modern laboratory facilities, computers, instrumentation, and extensive collections of specimens and data are available to students. Field study is an essential part of the graduate curriculum in geology, geophysics, and geochemistry, and special arrangements may be made for summer employment and field research on departmental projects and with industrial organizations and government agencies. In oceanography, sea-going observational research is an important part of the educational experience. In atmospheric science, climate studies, and oceanography, graduate study includes a mixture of theoretical and experimental studies sharing a common appreciation of the dynamics of the underlying processes.  

Entrance Requirements for Graduate Study  
In addition to the General Institute Requirements for admission listed in the section on Graduate Education, the department requires preparation equivalent to the curriculum for the Bachelor of Science in Earth, Atmospheric, and Planetary Sciences at MIT for graduate studies in that field. For atmospheric sciences, climate studies, meteorology, and oceanography, the most essential element is a sound preparation in mathematics and physics, supplemented if possible by some chemistry. Students taking their undergraduate work at other institutions are advised to
include in their programs the equivalent of the mathematics and physics contained in the MIT undergraduate curricula. If students are not fully prepared in certain of the fields or required subjects, they usually are asked to extend their studies in these areas while pursuing advanced work. The doctoral program can be entered without a Master of Science as a prerequisite.

**Joint Program with the Woods Hole Oceanographic Institution**

MIT and WHOI have established a program in oceanography that leads to a jointly awarded degree of Master of Science, Doctor of Philosophy, or Doctor of Science. For more information, see the program description at the end of Part 2.

**Master of Science in Earth and Planetary Sciences, in Atmospheric Sciences, or in Ocean Sciences**

The General Institute Requirements for the degree of Master of Science in Earth and Planetary Science, in Atmospheric Sciences, or in Ocean Sciences are described in the section on Graduate Education. An individual program of study and research is arranged to suit the special background, needs, and goals of each student. The program is worked out in detail by the student with his or her personal faculty advisor and a departmental committee. There are no foreign language requirements for the degree. Master’s students in oceanography and atmospheric sciences have access to the facilities of the joint MIT-WHOI program.

**Master of Science in Geosystems**

The Master of Science in Geosystems degree is open to students with undergraduate degrees in geoscience, physics, chemistry, mathematics, or engineering. The degree can be completed in one academic year and prepares students for scientific and management careers in the environmental, natural resources, and technical consulting industries by providing skills in computer simulation and modeling of complex natural systems, as well as scientific inference and data analysis. The program requires students to complete a 108-unit program consisting of nine subjects and a thesis project.

The following laboratory subject:

- 12.307 Weather and Climate Laboratory, LAB, CI-M, 12; 18.02, 8.01

**AREA 3 Planetary Science and Planetary Astronomy**

- 8.09 Physics II, 12, REST; 8.02*, 18.02
- 8.04 Quantum Physics I, 12, REST; 8.03*, 18.03*
- 8.044 Statistical Physics I, 12; 8.03, 18.03
- 12.008 Classical Mechanics: A Computational Approach, 12; 8.01, 18.03
- 12.420 Physics and Chemistry of the Solar System, 12; 8.03, 12.002, or permission of instructor

The following laboratory subject:

- 12.410 Observational Techniques of Optical Astronomy, 15, LAB, CI-M; 8.03

**AREA 4 Environmental Science**

- 12.097 Geology, 12
- 12.102 Environmental Earth Science, 12, REST
- 12.193 Strange Bedfellows: Science and Environmental Policy, 12, CI-M
- 12.085 Seminar in Environmental Science, 9; 12.120 and 12.103 or permission of instructor

Three subjects in one focus area:

- Biology focus: 1.01B/7.330 Fundamentals of Ecology, 12, REST; 7.012*
- Geology focus: 12.001* Organic Chemistry I, 12, REST; 5.11*
- Chemistry focus: 5.03 Principles of Inorganic Chemistry I, 12; 5.12
- 5.12 Organic Chemistry I, 12, REST; 5.11*
- 5.60 Thermodynamics and Kinetics, 12, REST; 18.02, 5.11*

Earth Science focus:

- 12.110 Sedimentary Geology, 12; 12.001*
- 12.165 Surface Processes and Landscape Evolution, 12; 18.03*, 12.001
- 12.216 Environmental Geophysics, 12; 18.03

12 units from the following field or laboratory subjects:

- 5.310 Laboratory Chemistry, 12; 5.12
- 12.113 Analytical Technique for Studying Environmental and Geologic Samples, 12, LAB
- 12.110 Experimental Investigations of the Charles River, 12, LAB
- 12.120 Environmental Earth Science Field Course, 6; 12.001*
- 12.159 Sedimentary and Surficial Geology Investigations, 12; 12.110*
- 12.162 Geological Image Interpretations, 12; 12.001*
- 12.265 Techniques in Remote Sensing, 6
- 12.307 Weather and Climate Laboratory, 12, LAB, CI-M

**Departmental Program Units That also Satisfy the GIRs**

Restricted Electives 6–27

One or two subjects selected with the approval of the faculty advisor from among EAPS concentration area electives, mathematics, and physics (24 units in Areas 1, 6–12 units in Areas 2, and 24–27 units in Area 3).

**AREA 1.** Choose two:

- 12.102, 12.104, 12.109, 12.110, 12.119, 12.159, 12.162, 12.163, 12.201, 12.207*;
- 12.214, 12.215

**AREA 2.** Choose one:

- 12.300, 12.301, 12.306, 12.310, 12.320

**AREA 3.** Choose one:

- 1.00, 6.001; Choose 1: 18.04, 18.05, 18.06, 18.075

**AREA 4.** Choose two from a focus:

- Biology: 1.080, 5.07, 5.08, 5.13, 5.43, 9.20, 10.333, 11.002, 11.122, 12.000, 17.32
- Chemistry: 20.104, 1.080, 1.082, 5.04, 5.07, 5.13, 5.61, 5.310, 10.333, 11.002, 11.122, 12.000, 12.300, 17.32

Unrestricted Electives 78

**Total Units Beyond the GIRs Required for SB Degree** 180

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

**Notes**

*Alternate prerequisites are listed in the subject description.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
Doctor of Philosophy and Doctor of Science

General Institute Requirements for the degree of Doctor of Philosophy or Doctor of Science are given in the section on Graduate Education. The department does not require candidates for the doctorate to present evidence of competence in a foreign language, but it strongly urges that candidates for the doctorate acquire intermediate competence in one or more languages. A specialized program of study and research is tailored to each student’s background, needs, and goals by the student in consultation with a faculty advisor and a departmental committee. A doctoral candidate’s program should be broad and include formal study in other departments in addition to the specialized subjects that prepare the candidate for thesis research. Thesis research normally begins immediately after successful completion of the general examination by the end of the second year. The general examination is intended to test the candidate’s aptitude and preparation for independent research.

Thesis research is closely supervised by one or more faculty members interested in and knowledgeable about the research topic, who are chosen by the student and may be members of other departments. The thesis is expected to meet high professional standards, and to be a significant original contribution to the scientific field.

Teaching and Research Assistantships

The department offers a considerable number of research and teaching assistantships each year. Research assistants work on one of the many research projects in the department, often related to the student’s thesis research. Teaching assistants assist in laboratory instruction or in the preparation of teaching materials and the grading of papers.

The department also offers several fellowships beyond normal teaching and research assistantships. Selection of individuals is based on the excellence of the applicant’s record.

Inquiries

Additional information regarding academic and current research programs in the department, admission requirements, assistantship appointments, and financial aid may be obtained by writing to the Department of Earth, Atmospheric, and Planetary Sciences, Education Office, Room 54-912, MIT, 617-253-3381.

RESEARCH LABORATORIES AND PROGRAMS

Earth Resources Laboratory

The Earth Resources Laboratory (ERL) is one of the premier research laboratories in the world in the areas of applied geophysics and quantitative geology. The lab studies the spatial heterogeneity of the earth’s upper crust through geophysical imaging, geological process modeling, and the interactions between rock pore systems and migrating fluids. Laboratory activities are centered around theoretical, experimental, and observational research programs in basic science that have both industrial and academic applications. Research at the lab is supported by industry and government agencies.

ERL’s major research activities include: elastic wave propagation in complex media; characterization of reservoir properties such as fracture density, in-situ stress, and fluid mobility from seismic and well log data; turbidite depositional dynamics; field mapping of reservoir scale geologic analogs in Western Africa; electrosismic phenomena; imaging and simulation of pore-scale fluid flow; borehole acoustics; reservoir imaging from surface and borehole seismic data; GPS measurements of crustal deformation in the Eastern Mediterranean, including the North Anatolian fault system in Turkey; and geophysical monitoring of groundwater contaminant movement.

ERL’s computation environment consists of a large network of workstations and personal computers, as well as the Reservoir Science Visualization Laboratory, which includes a number of high performance workstations running data analysis and visualization software. This facility is used to enhance and expand ERL’s research activities in petroleum reservoir imaging and monitoring, environmental geophysics, and geologic mapping and remote sensing. ERL also has a wide range of experimental facilities and equipment, including a large-scale (5m by 5m) sediment dynamics tank, and Ultrasonic Laboratory for seismic imaging and borehole experiments, and field equipment for seismic, electrical, and GPR surveys.

Further information can be obtained through ERL headquarters, Room E34-462, or by calling Professor John Grotzinger at 617-253-3498.

Center for Global Change Science

The Center for Global Change Science (CGCS) seeks to address long-standing scientific problems that impede our ability to accurately predict changes in the global environment. Established in 1990, CGCS is an interdepartmental organization that conducts research on global climate processes, climate observations, and past climate variations. Participants include faculty, staff, and students from a variety of natural science and engineering disciplines. The center’s activities also involve substantial multidisciplinary cooperative efforts focused on climate modeling, through the Climate Modeling Initiative (http://paoc.mit.edu/cmi/), and climate-policy research, through the Joint Program on the Science and Policy of Global Change (http://mit.edu/globalchange/).

For further information, see the center description in Part 1, Interdisciplinary Research and Study.

Joint Program on the Science and Policy of Global Change

The Joint Program on the Science and Policy of Global Change conducts independent analyses of climate-policy issues and research on climate science. It is a cooperative effort of the Center for Global Change Science and the Center for Energy and Environmental Policy Research that brings together natural and social scientists to address global environmental change and human-climate interaction. The program is a highly visible and well-funded effort, providing rigorous integrated assessment of the climate change issue to governments, industry, and the public. The cornerstone of the program’s research is an interacting set of models of the world economy (human activities) and the earth system (coupled ocean, atmosphere, land, and ecosystems). The program cooperates closely with the Ecosystems Center of the Marine Biological Laboratory in Woods Hole, MA; the MIT Climate Modeling Initiative; and other MIT environmental programs.

For further information see the program description in Part 1, Interdisciplinary Research and Study.
George R. Wallace, Jr. Astrophysical Observatory

The George R. Wallace, Jr., Astrophysical Observatory is a versatile facility for research and teaching optical astronomy. The observatory located in Westford, MA, has two optical telescopes with 16-inch and 24-inch diameters and unique electronic instrumentation. The telescopes are used in formal instruction for student research projects, and as testbeds for instrumentation to be used with larger telescopes.

Further information on the Wallace Observatory may be obtained by contacting Professor James L. Elliot, Department of Earth, Atmospheric, and Planetary Sciences, Room 54-422, MIT, 617-253-6308, jle@mit.edu, or from http://web.mit.edu/wallace/.

Wallace Geophysical Observatory

The George R. Wallace, Jr., Geophysical Observatory is a unique research facility designed to monitor ground motions and to aid in the development and testing of new seismic and other geophysical instrumentation. It is also a key component of MIT’s five-station seismic network in New England.

Located 35 miles north of Boston in Westford, MA, the observatory has a large, multi-room underground vault and a surface control room. The vault has a controlled temperature environment and instrument piers resting directly on the basement granite. The observatory contains sensitive seismometers and instruments for monitoring ground tilts and the earth’s tidal motions. The surface building houses a work area and control and recording instruments. Data from the observatory are telemetered directly to the Earth Resources Laboratory of the Department of Earth, Atmospheric, and Planetary Sciences. The data from the observatory and the New England Seismic Network are recorded, displayed, and analyzed by three dedicated COMPAQ computers, which are also connected to workstations to facilitate data sharing and transfers. Data from the observatory along with the numerous resources of the department provide a unique facility for undergraduates, graduate students, and staff to pursue research concerning the interior of the earth.

Further information may be obtained by contacting the director, Professor M. Nafi Toksöz, Room E34-440, MIT, 617-253-7852, email nafi@erl.mit.edu.

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Peter Hunter Stone, PhD
Professor of Climate Dynamics, Emeritus
Mathematics provides a language and tools for understanding the physical world around us and the abstract world within us. MIT’s Mathematics Department is one of the strongest in the world, representing a broad spectrum of fields ranging from the traditional areas of pure mathematics such as analysis, algebra, geometry, and topology, to applied mathematics areas such as combinatorics, computational biology, fluid dynamics, theoretical computer science, and theoretical physics.

Undergraduate students may elect one of three options leading to a degree in mathematics: applied mathematics; theoretical mathematics; and general mathematics. The general mathematics option provides a great deal of flexibility and is suitable for students who want to design their own programs in conjunction with their advisors. Additionally, the Mathematics with Computer Science degree is offered for students wishing to pursue their interests in mathematics and theoretical computer science within a single undergraduate program. Nearly one-half of the graduating seniors in mathematics are double majors. Popular second majors for these students include computer science, physics, and economics.

After graduation, our students find a variety of opportunities available to them. Some go on to graduate school in mathematics, computer science, and other fields such as medicine, finance, and engineering. Many begin careers in consulting, actuarial science, software engineering, and investment banking.

At the graduate level, the department offers the PhD in mathematics where students learn to conduct original research.

For more information, see the department website at http://www.math.mit.edu/.

UNDERGRADUATE STUDY

An undergraduate degree in mathematics provides an excellent basis for graduate work in mathematics or computer science, or for employment in such mathematics-related fields as systems analysis, operations research, finance, or actuarial science.

Because the career objectives of undergraduate mathematics majors are diverse, each undergraduate’s program is individually arranged through collaboration between the student and his or her faculty advisor. Students are encouraged to explore the various branches of mathematics, both pure and applied.

Undergraduates in mathematics are encouraged to elect an upper-level mathematics seminar during the junior or senior year. The experience gained from active participation in a seminar conducted by a research mathematician is particularly valuable for a student planning to pursue graduate work. These seminars additionally provide training in communicating mathematics effectively.

Three undergraduate programs lead to the degree Bachelor of Science in Mathematics: the General Mathematics option, the Applied Mathematics option for those who wish to specialize in that aspect of mathematics, and the Theoretical Mathematics option for those who expect to pursue graduate work in pure mathematics. A fourth undergraduate program leads to the degree Bachelor of Science in Mathematics with Computer Science; it is intended for students interested in theoretical computer science.

Bachelor of Science in Mathematics/
Course 18

General Mathematics Option
This option is the one followed by most students who major in mathematics. In addition to the General Institute Requirements, the requirements consist of 18.03 Differential Equations, or 18.034 Differential Equations, and eight 12-unit subjects in Course 18 of essentially different content, including at least six advanced subjects (first decimal digit one or higher). This leaves available 84 units of unrestricted electives. The requirements are flexible in order to accommodate several categories of students: students who pursue programs that combine mathematics with a related field (such as physics, economics, or management); students who are interested in both theoretical and applied mathematics; and students who choose mathematics as a general Institute major.

Applied Mathematics Option
Applied mathematics is the mathematical study of general scientific concepts, principles, and phenomena that, because of their widespread occurrence and application, relate or unify various disciplines. The core of the program at MIT concerns the following principles and their mathematical formulations: propagation, equilibrium, stability, optimization, computation, statistics, and random processes.

Sophomores interested in applied mathematics typically survey the field by enrolling in 18.310 and 18.311 Principles of Applied Mathematics. Subject 18.310, given only in the first term, is devoted to the discrete aspects of the study and may be taken concurrently with 18.03. Subject 18.311, given only in the second term, is devoted to continuous aspects and makes considerable use of differential equations.

The subjects in Group I of the program correspond roughly to those areas of applied mathematics that make heavy use of discrete mathematics, while Group II emphasizes those subjects that deal mainly with continuous processes. Some subjects, such as probability or numerical analysis, have both discrete and continuous aspects.

Students planning to go on to graduate work in applied mathematics should also take some basic subjects in analysis and algebra.

Theoretical Mathematics Option
Theoretical mathematics (or “pure” mathematics) is the study of the basic concepts and structures that underlie the mathematical tools used in science and engineering. Its purpose is to search for a deeper understanding and an expanded knowledge of mathematics itself.

Traditionally, pure mathematics has been classified into three general fields: analysis, which deals with continuous aspects of mathematics; algebra, which deals with discrete aspects; and geometry. The undergraduate program is designed so that students become familiar with each of these areas. Students may also wish to explore other topics such as logic, number theory, complex analysis, and subjects within applied mathematics.

The subject 18.100B Analysis I is basic to the program. Since this subject is strongly proof oriented, many students find an intermediate subject such as 18.06 Linear Algebra or 18.700 Linear Algebra useful as preparation.

The subject 18.701 Algebra I is more advanced and should not be elected until the student has had some experience with proofs (as in 18.100B or 18.700).
**Bachelor of Science in Mathematics with Computer Science/Course 18-C**

Mathematics and computer science are closely related fields. Problems in computer science are often formalized and solved with mathematical methods. It is likely that many important problems currently facing computer scientists will be solved by researchers skilled in algebra, analysis, combinatorics, logic and/or probability theory, as well as computer science.

The purpose of this program is to allow students to study a combination of these mathematical areas and potential application areas in computer science. Required subjects include linear algebra (18.06 or 18.700) because it is so broadly used; discrete mathematics (18.062) or 18.310) to give experience with proofs and the necessary tools for analyzing algorithms; and complex systems (6.033 or 6.170) where mathematical issues may arise. The required subjects covering complexity (18.404 or 18.400) and algorithms (18.410) provide an introduction to the most theoretical aspects of computer science.

Some flexibility is allowed in this program. In particular, students may substitute the more advanced subject 18.701 Algebra I for 18.06, and if they already have strong theorem-proving skills, may substitute 18.314 for 18.062 or 18.310.

**Minor Program in Mathematics**

The requirements for a Minor in Mathematics are as follows:

Six 12-unit subjects in mathematics, beyond the Institute calculus requirement, of essentially different content, including at least four advanced subjects (first decimal digit one or higher).

For a general description of the minor program, see Undergraduate Education in Part 1.

**Inquiries**

Inquiries regarding academic programs may be addressed to Joanne Jonsson, Undergraduate Mathematics Office, Room 2-108, MIT, 617-253-2416.

Additionally, the following information sheets are available in Room 2-108 and online at [http://www-math.mit.edu/undergraduate/](http://www-math.mit.edu/undergraduate/):

- What Math Subject Shall I Take?
- Careers in Mathematics
- Thinking of Majoring in Mathematics?

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**Bachelor of Science in Mathematics/Course 18**

**General Institute Requirements (GIRs)**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement (one subject can be satisfied by 18.03 or 18.034 in the Departmental Program)</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

**Communication Requirement**

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

**PLUS Departmental Program**

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.03 Differential Equations, 12; REST; 18.02*</td>
<td>132</td>
</tr>
<tr>
<td>or 18.034 Differential Equations, 12; REST; 18.02*</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives</td>
<td>96</td>
</tr>
<tr>
<td>To satisfy the requirements that students take two CI-M subjects, students must take two of: 18.091, 18.096, 18.100C, 18.104, 18.304, 18.424, 18.434, 18.504, 18.704, 18.821, 18.904, or 18.994</td>
<td></td>
</tr>
<tr>
<td>One from the above list and one of the following: 6.033, 6.111, or 8.06</td>
<td></td>
</tr>
</tbody>
</table>

**General Mathematics Option**

Eight 12-unit subjects of different content, including at least six advanced subjects (first decimal digit one or higher).

**Applied Mathematics Option**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.310 Principles of Applied Mathematics, 12; 18.02*</td>
<td></td>
</tr>
<tr>
<td>18.311 Principles of Applied Mathematics, 12; 18.03*</td>
<td></td>
</tr>
<tr>
<td>One of the following two subjects:</td>
<td></td>
</tr>
<tr>
<td>18.04 Complex Variables with Applications, 12; 18.03*</td>
<td></td>
</tr>
<tr>
<td>18.112 Functions of a Complex Variable, 12; 18.100</td>
<td></td>
</tr>
<tr>
<td>One of the following two subjects:</td>
<td></td>
</tr>
<tr>
<td>18.06 Linear Algebra, 12; REST; 18.02*</td>
<td></td>
</tr>
<tr>
<td>18.700 Linear Algebra, 12; 18.02</td>
<td></td>
</tr>
<tr>
<td>Four additional 12-unit Course 18 subjects from the following two groups with at least one subject from each group:(a)</td>
<td></td>
</tr>
<tr>
<td>Group I — Probability and statistics, combinatorics, computer science</td>
<td></td>
</tr>
<tr>
<td>Group II — Numerical analysis, physical mathematics, nonlinear dynamics</td>
<td></td>
</tr>
</tbody>
</table>

**Theoretical Mathematics Option**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.100B Analysis II, 12; 18.100, 18.700*</td>
<td></td>
</tr>
<tr>
<td>18.103 Fourier Analysis — Theory and Applications, 12; 18.100</td>
<td></td>
</tr>
<tr>
<td>An upper-level mathematics seminar(1) (12 units)</td>
<td></td>
</tr>
<tr>
<td>Two additional Course 18 subjects of essentially different content, with the first decimal digit one or higher (24 units)</td>
<td></td>
</tr>
</tbody>
</table>

**Departmental Program Units That also Satisfy the GIRs**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Units Beyond the GIRs Required for SB Degree**

No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.

**Notes**

*Alternate prerequisites are listed in the subject description.
(a) A list of acceptable subjects is available in Room 2-108.
(b) These seminars are 18.104, 18.504, 18.704, 18.904, and 18.994.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
The Mathematics Department offers programs covering a broad range of topics leading to the Doctor of Philosophy and the Doctor of Science degrees. Numerous formal and informal seminars, as well as a joint weekly mathematics colloquium sponsored alternately by MIT, Brandeis, Harvard, and Northeastern, supplement the subject offerings.

Entrance Requirements for Graduate Study

Students are expected to have one year of college-level natural science in addition to an undergraduate mathematics program approximating that of mathematics majors at MIT. Students may enter the applied mathematics program from any undergraduate field of concentration; however, special consideration is given to students with a strong scientific background.

Doctor of Philosophy and Doctor of Science

The Institute requirements for these degrees are given in the section on Graduate Education in Part 1. The details of the departmental requirements are explained in a set of notes available from the Mathematics Department. In outline, the requirements include a general qualifying examination to be taken in the third term of registration in the program and completion of a minimum of 132 units (registration in at least 11 graduate subjects). The decisive requirement is conducting original research in mathematics and summarizing the results of that research in a thesis.

For students in the pure mathematics program, the oral part of the general examination covers three areas chosen by the student in consultation with the chairperson of the Committee on Graduate Students. One of the three areas is examined in greater depth and normally becomes the field of specialization. The examiner in this area normally becomes the thesis advisor.

For students electing the applied mathematics program, the basic objective is a proper balance of specialization and diversity. A range of subjects is required, including at least one in discrete and one in continuous applied mathematics. By the end of the first year of study, each

Bachelor of Science in Mathematics with Computer Science/Course 18-C

General Institute Requirements (GIRs) Subjects
Science Requirement 6
Humanities, Arts, and Social Sciences Requirement 8
Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 18.03 or 18.034 and 6.001 in the Departmental Program] 2
Laboratory Requirement 1
Total GIR Subjects Required for SB Degree 17

Communication Requirement
The program includes a Communication Requirement of 4 subjects:
2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program Units
Required Subjects 87–90

18.03 Differential Equations, 12; REST; 18.02*
18.034 Differential Equations, 12; REST; 18.02*
6.001 Structure and Interpretation of Computer Programs, 15, REST
18.410 Introduction to Algorithms, 12; 6.001, 18.062*
18.06 Linear Algebra, 12; 18.02*
or
18.700 Linear Algebra, 12; 18.02

One subject from each of the following pairs:
18.062 Mathematics for Computer Science, 12; 18.01
18.110 Principles of Applied Mathematics, 12; 18.02
18.400 Automata, Computability, and Complexity, 12; 6.042*
or
18.404 Theory of Computation, 12; 18.062* 
6.033 Computer System Engineering, 12; 6.004
or
6.170 Laboratory in Software Engineering, 15; 6.001

Restricted Electives 72
Four additional Course 18 subjects and two additional Course 6 subjects.
The overall program must consist of subjects of essentially different content, and must include at least five Course 18 subjects with first decimal digit one or higher.
To satisfy the requirements that students take two CI-M subjects, students must take two of: 18.091, 18.096, 18.100C, 18.104, 18.304, 18.424, 18.436, 18.504, 18.704, 18.821, 18.904, or 18.994
or
One from the above list and one of the following:
6.033, 6.111, or 8.06

Departmental Program Units That also Satisfy the GIRs (27)

Unrestricted Electives 48–51

Total Units Beyond the GIRs Required for SB Degree 183

No subject can be counted both as part of the 17-subject GIRs and as part of the 183 units required beyond the GIRs.

Notes
*Alternate prerequisites are listed in the subject description.
(1) Recommended alternative.
For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
student must submit a plan of study for approval by the chairperson of the Applied Mathematics Committee. The general oral examination in applied mathematics tests the student’s competence in the area chosen for thesis research.

**Financial Support**
Most graduate students in mathematics are supported in full or in part by teaching assistantships, fellowships, or research assistantships. This support is renewed for students who are progressing satisfactorily, so that they are supported for a total of four years.

**Inquiries**
Additional information regarding academic or research programs in mathematics, admissions, or financial aid, may be obtained from Linda Okun, Graduate Mathematics Office, Room 2-233, MIT, 617-253-2689.

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Professor of Mathematical Logic, Emeritus
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Harold Stark, PhD
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Professor of Mathematics, Emeritus

2006-2007
The Department of Physics offers undergraduate, graduate, and postgraduate training, with a wide range of options for specialization.

The emphasis of both the undergraduate curriculum and the graduate program is on understanding the fundamental principles that appear to govern the behavior of the physical world, from phenomena in the small-scale domain of subatomic particles to the large-scale structure of the universe, spanning a spatial range stretching from 10^-18 m to 10^26 m. At each level of structural organization, active and exciting areas of investigation abound. Topics range from the basic constituents of matter (elementary particles), atomic and nuclear structure, through thermonuclear plasmas, physics at extremely low temperatures or extremely high pressures, to the evolution of stars, the large-scale structure of the universe, and the mystery of gravity.

The department has extensive facilities for experimental research, as described in the section on graduate study. Many of these are accessible to interested undergraduates in the context of the Undergraduate Research Opportunities Program. Students are encouraged to enrich their curriculum by taking advantage of this opportunity.

**UNDERGRADUATE STUDY**

**Bachelor of Science in Physics/Course 8**

An undergraduate degree in physics provides an excellent basis not only for graduate study in physics and related fields, but also for professional work in such fields as astrophysics, biophysics, engineering and applied physics, geophysics, management, law, or medicine. The undergraduate curriculum offers students the opportunity to acquire a deep conceptual understanding of fundamental physics. The core departmental requirements begin this process. The student then chooses one of two options to complete the degree. The focused option is designed for students who plan to pursue physics as a career. The flexible option is designed for those who are interested in other, perhaps non-traditional, career paths. Either option provides a considerable amount of time for exploration through electives. Students proceed at the pace and degree of specialization best suited to their individual capacities. Both options lead to the same degree: the Bachelor of Science in Physics.

### Bachelor of Science in Physics/Course 8

#### General Institute Requirements (GIRs)

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 8.03 or 8.04, and 18.03 or 18.034 in the Departmental Program]</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement [satisfied by 8.13 or 8.14 in the Departmental Program]</td>
<td>1</td>
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</tbody>
</table>

**Total GIR Subjects Required for SB Degree**

17

#### Communication Requirement

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

#### PLUS Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites are indicated in italics and subjects given only in the Independent Activities Period are indicated as IAP).

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.03 Physics II, 12, REST; 8.03*, 18.02</td>
<td>12</td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; 18.02*</td>
<td>10</td>
</tr>
<tr>
<td>or 18.034 Differential Equations, 12, REST; 18.02*</td>
<td>10</td>
</tr>
<tr>
<td>8.04 Quantum Physics I, 12, REST; 8.03*, 18.03*</td>
<td>12</td>
</tr>
<tr>
<td>8.044 Statistical Physics I, 12; 8.03, 18.03</td>
<td>12</td>
</tr>
</tbody>
</table>

**Physics: Flexible Option**

- 8.05 Quantum Physics II, 12; 8.04
- 8.20 Introduction to Special Relativity, 9, REST, (IAP); 8.01, 18.01
- 8.033 Relativity, 12; 8.01, 18.02
- One of the following experimental experiences:
  - 8.13 Experimental Physics I, 18, LAB, CI-M; 8.04
  - A laboratory subject of similar intensity in another department
  - An experimental research project or senior thesis
  - An experimentally oriented summer externship

**Physics: Focused Option**

- 8.033 Relativity, 12; 8.01, 18.02
- 8.05 Quantum Physics II, 12; 8.04
- 8.20 Introduction to Special Relativity, 9, REST, (IAP); 8.01, 18.01
- 8.033 Relativity, 12; 8.01, 18.02
- One of the following experimental experiences:
  - 8.13 Experimental Physics I, 18, LAB, CI-M; 8.04
  - A laboratory subject of similar intensity in another department
  - An experimental research project or senior thesis
  - An experimentally oriented summer externship

**Restricted Electives**

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>36–48</td>
</tr>
</tbody>
</table>

**Physics: Flexible Option**

At least one subject in the Department of Physics in addition to those listed above (12 units)

Three subjects forming one intellectually coherent unit in some area, not necessarily physics, subject to the approval of the department (16 units)

**Physics: Focused Option**

One subject in the Department of Mathematics beyond 18.03 (12 units)

Two subjects in the Department of Physics in addition to those listed above, including at least one of the following: 8.07, 8.08, and 8.09 (24 units)

**Departmental Program Units That also Satisfy the GIRs**

24–36

**Unrestricted Electives**

48–93
Physics: Focused Option

This option—which includes three terms of quantum mechanics, 36 units of laboratory experience, and a thesis—is ideal preparation for a career in physics. In the second year, students take 8.03 Physics III, 8.033 Relativity, 8.04 Quantum Physics I, and 8.044 Statistical Physics I. Important skills for experimentation in physics may be acquired by starting an Undergraduate Research Opportunities Program (UROP) project.

In the third year, students normally take laboratory subjects 8.13 and 8.14 Experimental Physics I and II, along with 8.05 and 8.06 Quantum Physics II and III. Students should also begin to take the restricted elective subjects, one in mathematics and at least two in physics. The mathematics subjects 18.04 Complex Variables with Applications, 18.075 Advanced Calculus for Engineers, and 18.06 Linear Algebra are particularly popular with physics majors. Topical elective subjects in astrophysics, biophysical chemistry, condensed matter, plasma, and nuclear and particle physics, allow students to gain an appreciation of the frontiers of modern physics. Students intending to go on to graduate school in physics are encouraged to take the theoretical physics sequence 8.07 Electromagnetism II, 8.08 Statistical Physics II, and 8.09 Classical Mechanics II.

An important component of this option is the thesis, which is a physics research project carried out under the guidance of a faculty member. Many thesis projects grow naturally out of UROP projects. Students should have some idea of a thesis topic by the middle of their junior year. A thesis proposal must be submitted before registering for thesis units and no later than Add Date of the fall term of the senior year.

A relatively large amount of elective time usually becomes available during the fourth year and can be used either to deepen one’s background in physics or to explore other disciplines.

Physics: Flexible Option

This option is designed for students who wish to develop a strong background in the fundamentals of physics and then build on this foundation as they prepare for career paths that may not involve a graduate degree in physics. In the past, many students have found an understanding of the basic concepts of physics and an appreciation of the physicist’s approach to problem solving an excellent preparation for careers in business, law, medicine, or engineering. This option should be even more attractive today in light of the growing spectrum of nontraditional, technology-related career opportunities.

The option begins with the core subjects 8.01, 8.02, 8.03, 8.044, and 8.04. Students round out their foundation material with either an additional quantum mechanics subject (8.05) or a subject in relativity (8.20 or 8.033). There is an experimental requirement of 8.13 or, with the approval of the department, a laboratory subject of similar intensity in another department, an experimental research project or senior thesis, or an experimentally oriented summer externship. An exploration requirement consists of one elective subject in physics.

Students following this option must complete a focus requirement—three subjects forming one intellectually coherent unit in some area (not necessarily physics), subject to the approval of the department and separate from those used by the student to satisfy the HASS requirement. Areas of focus chosen by students in the past include astronomy, biology, computational physics, nanotechnology, history of science, science and technology policy, philosophy, and science teaching. Some students may choose to satisfy their experimental and exploration requirements in the same area as their focus; others may opt for greater breadth by choosing other fields to fulfill these requirements.

Students can satisfy the departmental portion of the Communication Requirement by taking two of the following of subjects: 8.06, 8.13, or 8.287J. The department may accept substitution of one of the department’s two required CI-M subjects with a CI-M subject in another department if it forms a natural part of the student’s physics program.

Although students may choose this option at any time in their undergraduate career, many make this choice during their sophomore year in order to have enough time to craft a program that best suits their individual needs. Specific subject choices for the experimental and focus requirements require the written approval of the associate department head for education.

Cambridge-MIT Exchange

The Physics Department participates in the junior-year exchange program with Cambridge University, in the United Kingdom, through the Cambridge-MIT Exchange (CME). Students with broad interests and a desire to experience a different educational environment are encouraged to explore this unique opportunity. Interested students should consult the Year or Term Away section of the chapter on Undergraduate Education in Part 1, then contact the department’s CME coordinator, Professor Thomas Greytak.

Minor Programs

The Minor in Physics provides a solid foundation for the pursuit of a broad range of professional activities in science and engineering. The requirements for a Minor in Physics are 18.03 or 18.034, plus any five Course 8 subjects beyond the General Institute Requirements.

Students should submit a completed Minor Application Form to Physics Academic Programs, Room 4-315. The Physics Department’s minor coordinator is Brian Canavan. For more information on minor programs, see Undergraduate Education in Part 1.
The Minor in Astronomy, offered jointly with the Department of Earth, Atmospheric, and Planetary Sciences, covers the observational and theoretical foundations of astronomy. The minor requires seven subjects as follows:

Astronomy, Mathematics, and Physics
Required subjects: 8.03, 8.282/12.402I, 18.03 or 18.034

Astrophysics
Choose one: 8.284, 8.286, 8.292I/12.330I

Planetary Astronomy
Choose one: 12.008, 12.400

Observations
8.287/12.410

Independent Project in Astronomy
Choose one: 8.UR, 8.ThU, 12.UR, 12.ThU, 12.411

Four of the subjects used to satisfy the requirements for the astronomy minor may not be used to satisfy any other minor or major.

Inquiries
Additional information concerning degree programs and research activities may be obtained by writing to Professor Thomas J. Greytak or to Physics Academic Programs, Room 4-315, MIT, 617-253-4841.

GRADUATE STUDY

The Physics Department offers programs leading to the degrees of Master of Science in Physics, Doctor of Philosophy, and Doctor of Science.

Entrance Requirements for Graduate Study
Students intending to pursue graduate work in physics should have as a background the equivalent of the requirements for the Bachelor of Science in Physics from MIT. However, students may make up some deficiencies over the course of their graduate work.

Master of Science in Physics
The requirements for the Master of Science in Physics are the General Institute Requirements listed under Graduate Education in Part 1. The master’s thesis must represent a piece of independent research work in any of the fields described below, and must be carried out under the supervision of a department faculty member. No fixed time is set for the completion of a master’s program; two years of work is a rough guideline. There is no language requirement for this degree.

Doctor of Philosophy and Doctor of Science
Candidates for the Doctor of Philosophy or Doctor of Science are expected to enroll in those basic graduate subjects that prepare them for the general examination, which must be passed no later than in the seventh term after initial enrollment. No specific subjects of study are prescribed, except for the requirement of two subjects in the candidate’s doctoral research area and two subjects outside the candidate’s field of specialization (breadth requirement). Half of the breadth requirement may be satisfied through a departmentally approved industrial internship. The doctoral thesis must represent a substantial piece of original research, carried out under the supervision of a department faculty member.

The Physics Department faculty members offer subjects of instruction and are engaged in research in a variety of fields in experimental and theoretical physics. This broad spectrum of activities is organized in the divisional structure of the department, presented below. Graduate students are encouraged to contact faculty members in the division of their choice to inquire about opportunities for research, and to pass through an apprenticeship (by signing up for Special Problems in Graduate Physics) as a first step toward an engagement in independent research for a doctoral thesis.

Research Divisions
The Astrophysics Division of the department has a varied program of instrument development and ground-based and satellite observations across the entire electromagnetic spectrum, with principal emphasis on the radio, optical, and x-ray bands. Theoretical work emphasizes high energy phenomena, stellar evolution, galactic structure, solar oscillations, and cosmology. Other areas of study include interplanetary and astrophysical plasmas, gravitational radiation, and the cosmic microwave background. See also the listing for Haystack Observatory in the section on Interdisciplinary Research and Study in Part 1.

Research activities in the Division of Nuclei and Particles include the broad fields of nuclear reaction and heavy ion physics, intermediate-energy nuclear structure physics, and high-energy fundamental particle physics. The experimental research in these areas is based on MIT’s 1 GeV Bates Linear Accelerator and on the accelerators at Brookhaven National Laboratory, the Fermi National Accelerator Laboratory in Batavia, Illinois, the Stanford Linear Accelerator, CERN (Geneva), the electron-positron collider at DESY (Hamburg, Germany), and the Gran Sasso underground laboratory at Frascati (Italy). Further information appears in the section on Interdisciplinary Research and Study in Part 1 under Laboratory for Nuclear Science.

The large and dynamic program in Condensed Matter, Atomic, and Plasma Physics provides students with a wide spectrum of research opportunities. Current topics in condensed matter include electron transport and critical phenomena in one, two, and three dimensions, mesoscope physics, and high temperature superconductivity. Atomic physics in the division involves ultra-high resolution laser spectroscopy, the trapping and cooling of atoms with lasers, and Bose-Einstein condensation. There are strong plasma programs in magnetically confined fusion and free electron lasers. Several faculty are applying the techniques of modern physics to current problems in medicine and biology. Extensive facilities are available on campus for the preparation and characterization of advanced materials and for work with high magnetic fields, low temperatures, and sub-micron structures. Scattering studies are being carried out at the Advanced Proton Source at Argonne National Laboratory and the NIST Center for Neutron Research in Gaithersburg, Maryland.

The chief emphasis of Nuclear and Particle Theory research at the Center for Theoretical Physics is on understanding the fundamental particles of nature, as revealed by their interactions and by their decay, and on the charac-
teristic quantum modes of motion systems composed of strongly interacting particles such as atomic nuclei. Work is also conducted on theoretical astrophysics as well as on the properties of other forms of matter. In all of this research, close contact is maintained with experimentalists, both within MIT and elsewhere.

The Center for Theoretical Physics houses a fairly large group of theorists including professional staff, postdoctoral fellows, senior visitors, and graduate students engaged in research in theory. Opportunities for communication and collaboration are maximized within the center; lively interaction among the many specialists in the various areas of interest is characteristic of this MIT group and is one of the major sources of the center’s strength.

Much of the research in the department is carried out as part of the work of various interdisciplinary laboratories and centers, including the Laboratory for Nuclear Science, Research Laboratory of Electronics, Spectroscopy Laboratory, Center for Materials Science and Engineering, Kavli Institute for Astrophysics and Space Research, Francis Bitter Magnet Laboratory, Microsystems Technology Laboratories, Plasma Science and Fusion Center, and the Program on Sciences and Technology and International Security. These facilities, most of which are described under Interdisciplinary Research and Study in Part 1, provide close relationships among the research activities of a number of MIT departments and give students opportunities for contact with research carried out in disciplines other than physics.

Inquiries
Additional information on degree programs, research activities, admissions, financial aid, teaching and research assistantships may be obtained by writing to Professor Thomas J. Greytak, Room NE25-4023, MIT, 617-253-6818.

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Professor of Physics, Emeritus
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Professor of Physics, Emeritus
Hale Van Dorn Bradt, PhD
Professor of Physics, Emeritus
Bernard Flood Burke, PhD
Professor of Physics, Emeritus
George Whipple Clark, PhD
Professor of Physics, Emeritus
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Professor of Physics, Emeritus
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Professor of Physics, Emeritus
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Professor of Physics, Emeritus
Harald A. Enge, PhD
Professor of Physics, Emeritus
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Professor of Physics, Emeritus
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Professor of Physics, Emeritus
Kerson Huang, PhD
Professor of Physics, Emeritus
Robert Inslee Hulsizer, Jr., PhD
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Karl Uno Ingard, PhD
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Physics, Emeritus
Ali Javan, PhD
Professor of Physics, Emeritus
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Rainer Weiss, PhD
Professor of Physics, Emeritus
Peter Adalbert Wolff, PhD
Professor of Physics, Emeritus
Physics Industry Forum
James Edward Young, PhD
Professor of Physics, Emeritus
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Joint Program with Woods Hole Oceanographic Institution 322
Leaders for Manufacturing 311
Operations Research 311
Polymer Science and Technology 311
System Design and Management 312
Technology and Policy 312
Part 2

Interdisciplinary Graduate Programs

Interdisciplinary Graduate Degrees Offered

<table>
<thead>
<tr>
<th>Computation for Design and Optimization</th>
<th>Course CSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM  Computation for Design and Optimization</td>
<td>Computational and Systems Biology</td>
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<td>Harvard-MIT Division of Health Sciences and Technology</td>
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<td>SM  Biomedical Informatics</td>
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<tr>
<td>SM  Health Sciences and Technology</td>
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<tr>
<td>MEng  Biomedical Engineering</td>
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<tr>
<td>MD  Medical Sciences (degree from Harvard Medical School)</td>
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<tr>
<td>ScD, PhD  Bioinformatics and Integrative Genomics</td>
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<td>ScD, PhD  Biomedical Engineering</td>
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<td>ScD, PhD  Electrical and Medical Engineering</td>
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<td>ScD, PhD  Health Sciences and Technology</td>
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<td>ScD, PhD  Mechanical and Medical Engineering</td>
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<td>ScD, PhD  Medical Engineering</td>
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<td>ScD, PhD  Medical Physics</td>
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<td>ScD, PhD  Radiological Sciences</td>
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<tr>
<td>ScD, PhD  Speech and Hearing Bioscience and Technology</td>
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Note: Many departments make it possible for a graduate student to pursue a simultaneous master’s degree.

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<tr>
<th>Oceanography and Applied Ocean Science and Engineering</th>
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<td>Engineer  Applied Ocean Science and Engineering</td>
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<td>ScD, PhD  Applied Ocean Science and Engineering</td>
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<td>ScD, PhD  Biological Oceanography</td>
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<td>ScD, PhD  Chemical Oceanography</td>
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<td>ScD, PhD  Marine Geology and Geophysics</td>
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<td>ScD, PhD  Physical Oceanography</td>
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Note: With the exception of engineering, the SM is only available as an interim degree for doctoral candidates or for those who leave the program before the completion of the doctoral degree.

Leaders for Manufacturing

SM/IMBA  Engineering/Management

Operations Research

SM  Operations Research
PhD  Operations Research

Polymer Science and Technology

PhD  Polymer Science and Technology

System Design and Management

SM  Engineering and Management

Technology and Policy

SM  Technology and Policy

At MIT, students and faculty from different fields work together in a multitude of interdisciplinary programs that cut across departmental or school boundaries. The programs listed in this section offer a variety of interdisciplinary graduate degrees.

Computation for Design and Optimization Program

Computation for Design and Optimization (CDO) is an interdisciplinary master’s degree program in the School of Engineering. The program provides students with a strong foundation in computational approaches to the design and operation of complex engineering and scientific systems.

The CDO program educates students in the formulation, analysis, implementation, and application of computational approaches to designing and operating engineered systems. The curriculum is designed with a common core that serves all engineering disciplines, and an elective component that focuses on particular applications. The program emphasizes:

- Breadth through introductory courses in numerical analysis and simulation, optimization, and applied probability
- Depth in optimization methods and numerical methods for partial differential equations
- Multidisciplinary aspects of computation
- Hands-on experience through projects, assignments, and a master’s thesis

CDO-affiliated faculty are drawn from departments in the Schools of Engineering, Science, and Management, including Aeronautics and Astronautics, Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering and Computer Science, Mechanical Engineering, Mathematics, and Management.

The research interests of CDO faculty cover many computationally intensive areas in engineering, science, and mathematics, including micromachined devices, guidance/control systems, imaging systems, distribution networks, telecommunication systems, and transportation systems. CDO faculty research encompasses applications in aircraft design, materials design, manufacturing operations scheduling, micromachined device design/optimization, and applied optimization in operations and industrial engineering.

For further information, contact Laura Rose, Room E40-143, MIT, 617-253-9303, email cdo_info@mit.edu, or visit http://mit.edu/cdo-program/.

Computational and Systems Biology Program

The Computational and Systems Biology PhD program is an Institute-wide program that has been jointly developed by the Department of Biology, the Department of Electrical Engineering and Computer Science, and the Biological Engineering Division. The program integrates biology, engineering, and computation to address complex problems in biological systems, and CSB PhD students have the opportunity to work with CSBI faculty from across the Institute. The curriculum has a strong emphasis on foundational material to encourage students to become creators of future tools and technologies, rather than merely practitioners of current approaches.

See the full program description on page 313.
Harvard-MIT Division of Health Sciences and Technology

Founded more than 35 years ago, the Harvard-MIT Division of Health Sciences and Technology (HST) is one of the oldest and largest biomedical engineering and physician-scientist training programs in the United States and the longest-standing collaboration between Harvard and MIT.

HST’s unique interdisciplinary educational program brings engineering as well as the physical and biological sciences from the scientist’s bench to the patient’s bedside. Conversely, it brings clinical insight from the patient’s bedside to the laboratory bench. In this way, HST students are trained to have deep understanding of engineering, physical sciences, and the biological sciences, complemented with hands-on experience in the clinic or in industry; and they become conversant with the underlying quantitative and molecular aspects of medicine and biomedical science.

See the full program description on page 315.

Joint Program with Woods Hole Oceanographic Institution

MIT and the Woods Hole Oceanographic Institution on Cape Cod offer joint doctoral degrees in oceanography and doctoral, professional, and master’s degrees in oceanographic engineering. These graduate programs draw from the faculty and staff of both institutions. Students accepted to the Joint Program have access to the extensive intellectual and physical resources available for advanced study at both Woods Hole and MIT.

See the full program description on page 322.

Leaders for Manufacturing Program

The Leaders for Manufacturing (LFM) program is an educational and research partnership between global operations companies and MIT’s School of Engineering and the MIT Sloan School of Management. Its objective is to discover, codify, teach, and otherwise disseminate guiding principles for world-class manufacturing and operations.

The LFM program combines graduate education in engineering and management for those with two or more years of work experience who aspire to leadership positions in manufacturing or operations companies. This rigorous 24-month program combines subjects in technology and management. A required 6.5-month internship provides opportunity to complete a research project on site at one of LFM’s partner companies. The internship leads to a dual-degree thesis, culminating in two master’s degrees—an SM or MBA and an SM in Engineering. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering master’s programs in:

- Aeronautics and Astronautics
- Biological Engineering
- Chemical Engineering
- Civil and Environmental Engineering
- Electrical Engineering and Computer Science
- Engineering Systems
- Materials Science and Engineering
- Mechanical Engineering

For additional information, see the program description under the Engineering Systems Divison or the Sloan School of Management in Part 2 or visit http://lfm.mit.edu/.

Operations Research Programs

Operations research is the discipline of applying advanced analytical methods to help make better decisions. It uses mathematical modeling, analysis, and optimization in a holistic approach to improving our knowledge of systems and designing useful, efficient systems. Its applications range from engineering to management, and from industry to the public sector.

Operations research (OR) has helped advance the mathematics of optimization, applied probability, and statistics. OR researchers, collaborating with colleagues in related fields, have created innovative methods for pricing goods and services, and for marketing them. They have contributed to improving transportation, developing new financial instruments and auctions, and analyzing biological and medical information, as well as many more areas. In today’s complex and interconnected world, the rigorous techniques and methodologies of operations research have become especially important aids to informed decision making.

The Operations Research Center coordinates an SM program and a PhD program, providing a strong background in OR theory as well as the practical techniques used in building models for a wide variety of applications.

Founded as an interdepartmental program, the Operations Research Center has maintained its interdisciplinary roots. Its faculty comes from nine different departments at MIT, including the Sloan School of Management, five of the engineering departments, the Department of Mathematics, the Department of Economics, and the Department of Urban Studies and Planning.

Information about the Operations Research Center and its degree programs is available on the ORC website at http://web.mit.edu/orc/www/.

For further information, contact Laura Rose, Room E40-143, MIT, 617-253-9303, or email lrose@mit.edu.

Program in Polymer Science and Technology

The Schools of Engineering and Science have established a graduate-level Program in Polymer Science and Technology (PPST). It is open to qualified students admitted to the graduate program of any MIT department.

PPST consists of an initial academic phase in which all students participate (regardless of previous background and research interest); followed by research in a selected area of specialization. The program leads to the doctoral degree; if desired, a master’s degree can be obtained through the graduate program.

The core curriculum, taken by all students, provides a common base in the field of polymers. It is broad, rigorous, and covers both elementary and advanced subjects spanning the entire range from the molecular level to the continuum. This curriculum takes up the first two semesters in the graduate program.

The transition from the academic phase to research is marked by the qualifying exam, which consists of both oral and written sections. The exams are offered at the end of each spring term and are based on the PPST core curriculum. Successful completion of the exam leads to selection of a research project and the preparation and defense of a thesis proposal.

Any participating faculty member at MIT can act as a research supervisor. The thesis supervisor(s) advises the graduate student on a continuing basis throughout the time of the research project. Completion and success-
ful defense of the thesis before PPST and departmental faculty fulfill the requirements for the doctoral degree.

For more information, including admission and financial aid procedures, contact the director, Professor Gareth McKinley, Room 3-250, MIT, 617-258-0754, or visit http://web.mit.edu/ppst/.

**System Design and Management Program**

MIT’s System Design and Management (SDM) program, offered jointly by the School of Engineering and the MIT Sloan School of Management, is a master’s program for professional engineers who seek to build upon their technical backgrounds and advance to positions of leadership in their profession.

The program leads to a Master of Science in Engineering and Management, and represents a partnership of industry, government, and MIT for educating technically grounded leaders of 21st-century enterprises. It is MIT’s first degree program to be offered with a distance learning option in addition to a full-time in-residence option.

For additional information, see the program description under the Engineering Systems Division or the Sloan School of Management in Part 2 or visit http://sdm.mit.edu/.

**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. To prepare participants for effective professional practice, TPP stresses effective leadership and communication. It also encourages students to participate in TPP’s summer internship program, which places students in government and industry in the United States and around the world.

Many students combine the TPP curriculum with complementary subjects to obtain dual degrees in TPP 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 under the Engineering Systems Division in Part 2, or visit http://tppserver.mit.edu/.
The emerging field of computational and systems biology represents an integration of concepts and ideas from the biological sciences, engineering disciplines, and computer science. Recent advances in biology, including the human genome project and massively parallel approaches to probing biological samples, have created a new opportunity to focus on understanding biological problems from a systems perspective. Systems modeling and design are well established in engineering disciplines but are relatively new to biology. Advances in computational and systems biology require multidisciplinary teams with skill in applying principles and tools from engineering and computer science to solve problems in biology and medicine. To provide education in this emerging field, the Computational and Systems Biology (CSB) program integrates MIT’s world-renowned disciplines in biology, engineering, math and computer science. Graduates of the program will be uniquely prepared to develop new methods, make novel discoveries and establish new paradigms. They will also be well-positioned to assume critical leadership roles in both academia and industry, where this new area is becoming increasingly important.

At MIT, research and education in Computational and Systems Biology are characterized by “the four M’s”—measurement, mining, modeling, and manipulation, with many diverse research groups working in these complementary areas. Efforts in measurement emphasize the systematic collection of data and the development of new experimental methods (e.g., using microfabrication). Research in mining and modeling aims to develop new algorithms to identify underlying relationships in large datasets, and to capture these in predictive models. Finally, design is an important facet of systems biology where the goal is to make rational modifications to biological systems. This type of manipulation provides a test of understanding and promises a route to practical advances in biotechnology and medicine. The strong focus on building detailed, quantitative, and predictive models of biological systems is a defining feature of the MIT program. Such models form the basis of understanding and the foundation of design.

More than 90 faculty members at MIT participate in MIT’s Computational and Systems Biology Initiative (CSBi). These investigators span nearly all departments in the School of Science and the School of Engineering. Thus, students in the CSB graduate program can pursue thesis research in a wide variety of different laboratories. It is also possible for students to arrange collaborative thesis projects with joint supervision from faculty members with different areas of expertise. Areas of active research include computational biology and bioinformatics, gene and protein networks, molecular biophysics, cell and tissue engineering, predictive toxicology and metabolic engineering, imaging and image informatics, instrumentation engineering, nanobiology and Microsystems, biological design and synthetic biology, neurosystems biology, and cancer biology.

The CSB PhD program is an Institute-wide program that has been jointly developed by the Department of Biology, the Department of Electrical Engineering and Computer Science, and the Biological Engineering Division. The program integrates biology, engineering, and computation to address complex problems in biological systems, and CSB PhD students have the opportunity to work with CSBi faculty from across the Institute. The curriculum has a strong emphasis on foundational material to encourage students to become creators of future tools and technologies, rather than merely practitioners of current approaches. Applicants are required to have an undergraduate degree, preferably with dual emphasis in biology (or a related field) and also in computer science, math, physics or an engineering discipline.

All students pursue a core curriculum that includes classes in biology and computational biology, along with a literature-based class in computational and systems biology. Advanced electives in science and engineering enhance both the breadth and depth of each graduate’s education. During their first year, in addition to coursework, students carry out rotations in research groups to gain a broader exposure to work at the frontier of this field, and to identify a suitable laboratory in which to do their thesis research. CSB students also serve as teaching assistants during one term in the second year to further develop their communication skills and facilitate their interactions across disciplines. Students also participate in training in the responsible conduct of research, because multidisciplinary research spans different academic cultures and modes of operation. The total length of the program, including coursework, qualifying examinations, thesis research, and preparation of the thesis is roughly five years.

Curriculum

The CSB curriculum has two components. The first is a core that provides foundational knowledge of both biology and computational biology. The second is a customized program of electives that are selected by each student in close consultation with members of the CSB graduate committee. The goal is to allow students broad latitude in defining their individual area of interest, but at the same time to provide oversight and guidance to ensure that they receive rigorous and thorough training.

Core Curriculum

The core curriculum consists of three classroom subjects plus a set of four two-month rotations in different research groups. The classroom subjects fall into three areas described below.

Modern Biology (One Subject): A term of modern biology at MIT strengthens the biology base of all students in the program. Subjects in cell biology, molecular biology, neurobiology, biochemistry, or genetics fulfill this requirement. The particular course taken by each student will depend on their background and will be determined in consultation with graduate committee members.

Computational Biology (One Subject): A term of computational biology provides students with a background in the application of computation to biology, including analysis and modeling of sequence, structural, and systems data. This requirement can be fulfilled with “Foundations of Computational and Systems Biology.”

Topics in Computational and Systems Biology (One Subject): All first-year students in the program participate in “Topics in Computational and Systems Biology,” a literature-based exploration of current frontiers and paradigms in this emerging field. This subject is limited to students in the CSB PhD program in order to build a strong community among the class. It is the only subject in the program with such a limitation.

Research Group Rotations (Four Rotations): To assist students with lab selection and provide
a range of research activities in computational and systems biology, students participate in four two-month long research rotations during their first year. Students are encouraged to gain experience in experimental and computational approaches taken across different disciplines at MIT.

**Advanced Electives**

The requirement of four advanced electives is designed to develop both breadth and depth for students in the CSB PhD program. The electives add to the base of the diversified core and contribute strength in areas related to student interest and research direction. To develop depth, two of the four advanced electives must be in the same area (department). To develop breadth, at least one of the electives must be from an engineering discipline and at least one from a biology-related field. Each student will design a program of advanced electives that satisfies the distribution and area requirements in close consultation with members of the graduate committee.

**Additional Subjects:** As is typical for students in other doctoral programs at MIT, CSB PhD students may take classes beyond the required diversified core and advanced electives described above. These additional subjects can be used to add breadth or depth to the proposed curriculum, and might be useful to explore advanced topics considered for the thesis research in later years. The CSB Graduate Committee will work with each graduate student to develop a path through the curriculum appropriate for his or her background and research interests.

**Qualifying Exams:** In addition to coursework and a research thesis, each student must pass a written and an oral qualifying examination in the second year. The written examination involves preparing a research proposal based on the student’s thesis research, and presenting the proposal to the examination committee. This process provides a strong foundation for the thesis, incorporating new research ideas and refinement of the scope of the research project. The oral examination is based on the coursework taken and on related published literature. The qualifying exams are designed to develop and demonstrate depth in a selected area (the area of the thesis research) as well as breadth of knowledge across the field of computational and systems biology.
HARVARD-MIT DIVISION OF HEALTH SCIENCES AND TECHNOLOGY

Founded more than 35 years ago, the Harvard-MIT Division of Health Sciences and Technology (HST) is one of the oldest and largest biomedical engineering and physician-scientist training programs in the United States and the longest-standing collaboration between Harvard and MIT.

HST’s unique interdisciplinary educational program brings engineering as well as the physical and biological sciences from the scientist’s bench to the patient’s bedside. Conversely, it brings clinical insight from the patient’s bedside to the laboratory bench. In this way, HST students are trained to have deep understanding of engineering, physical sciences, and the biological sciences, complemented with hands-on experience in the clinic or in industry; and they become conversant with the underlying quantitative and molecular aspects of medicine and biomedical science. Within the division, more than 400 graduate students work with eminent faculty and affiliated faculty members from throughout the MIT and Harvard communities.

In addition to its outstanding record of accomplishment for research in human health care, HST educational programs are distinguished by three key elements:

- A strong quantitative orientation
- Required hands-on experience in a clinical or industry setting
- A focused interdisciplinary research project

HST offers eight multidisciplinary graduate degree options:

- Medical Sciences MD Program
- Medical Engineering and Medical Physics Doctoral Program
  Concentrations include:
  - Bioinformatics and integrative genomics
  - Biomedical imaging and bio-optics
  - Cellular and molecular bioengineering/biophysics
  - Biomechanics and biofluidics
  - Systems physiology
  - Biomedical instrumentation and devices
  - Regenerative biomedical technologies
- Speech and Hearing Bioscience and Technology Doctoral Program
- Radiological Sciences Joint Program
- Biomedical Enterprise Master’s Program
- Biomedical Informatics Training Program
- Clinical Investigator Training Program
- Master of Engineering in Biomedical Engineering

MASTER’S PROGRAMS

Biomedical Enterprise Program
Launched in 2002 as a collaboration with the MIT Sloan School of Management, HST’s Biomedical Enterprise Program (BEP) is designed for individuals with business experience and a strong foundation in science and engineering. BEP prepares students for leadership roles in the transfer of new technologies from concept through product development to clinical adoption in the context of existing companies or newly established ventures.

Acknowledging that medical innovations in laboratory research and clinical care benefit society only when they become commercial products and services, BEP offers a unique curriculum that leverages the strengths of HST, MIT Sloan, Harvard Medical School (HMS), and the affiliated hospitals. BEP students take preclinical and engineering courses alongside HST’s MD and PhD students, and business courses with other MIT Sloan students. They participate in unique integrative courses designed to address the specific needs of starting, growing, and managing a biomedical enterprise. These courses were developed and are taught by a team of HST and Sloan faculty, including several local entrepreneurs. Also included in the curriculum is a hands-on hospital-based clinical experience that pairs students with physician-scientists and provides insight into the hospital environment and patient care.

BEP offers two dual-degree options for individuals who need training in both management and science, and a one-year degree option for business executives who already have a graduate degree in management. The dual-degree option leads to an MBA or SM degree from MIT Sloan and an SM degree from HST. The single-degree option leads to the SM degree from HST.

Master of Engineering in Biomedical Engineering

The Master of Engineering in Biomedical Engineering (MEBE) is offered jointly by HST and the Biological Engineering Division. This program aims to educate students at the interface between engineering and biology or medicine, preparing them for leadership positions in the medical products, pharmaceutical, and biotechnology industries. The MEBE program is a five-year program leading to a bachelor’s degree in a science or engineering discipline and a Master of Engineering in Biomedical Engineering. The bioengineering (BE) track, emphasizing a unification of engineering and biology, operates under the auspices of the Biological Engineering Division. The medical engineering (ME) track emphasizes engineering applications in systems physiology and clinical medicine and is offered under the auspices of HST. It is of particular value to students interested in applying biomedical engineering to the basic understanding of disease processes in the post-genomic era, and is designed for individuals desiring a medical and clinical focus in their careers.

While the two MEBE tracks have a similar overall structure and academic demands, students in the ME track take subjects that enable them to apply engineering expertise to problems in the medical and clinical sciences. In contrast, the BE track is based on subjects that view biological systems from an engineering perspective, using biology as one of the foundational sciences for engineering, along with physics, chemistry, and mathematics. Admission to the MEBE program requires candidates to demonstrate adequate quantitative and engineering credentials through coursework, usually as part of an undergraduate degree program. Students interested in applying to the MEBE program should submit a standard MIT graduate application by the end of their junior year. Detailed program objectives and the requirements for each track are listed under the Biological Engineering Division in Part 2. Additional information can be obtained by contacting Professor Roger Mark at 617-253-7818 (ME track) or Professor Roger Kamm at 617-253-5330 (BE track).

Master of Health Sciences and Technology

HST offers a general master’s degree program that can be coupled to other degree programs, such as the MD degree described below. To accommodate a wide range of student interests, the curriculum for the Master of Health Sciences
and Technology degree is determined by agreement between the student and his or her advisor. There are no specific requirements other than the Institute requirement for 66 subject units and a thesis. In each case, the Institute requirement for the master’s degree must be satisfied. Further information can be obtained from HST’s Office of Academic Affairs, Room E25-518, telephone 617-258-7084.

**DOCTORAL PROGRAMS**

**Medical Engineering and Medical Physics**

The doctoral program in Medical Engineering and Medical Physics (MEMP) provides a thorough grounding in a classical discipline of engineering or physics together with extensive preparation in human biology, basic medical science, clinical medicine, and the role of technology in patient care.

The MEMP curriculum has four major components: an intensive graduate program in a science or engineering department that includes electives in biomedical engineering subjects; a series of subjects in biomedical sciences taken together with the HST MD students, which promotes understanding of the fundamental biological processes in cells, tissues, and organs; specialized clinical training, which prepares the student to conduct effective research in patient-care environments and to thoroughly understand the process of medical decision making and the role of science technology in health-care delivery; and doctoral thesis research on a fundamentally important problem in medical engineering or medical physics. The five-to-seven-year program leads to the PhD or ScD degree awarded by MIT, or the PhD degree awarded by the Harvard Faculty of Arts and Sciences.

MEMP graduates are well qualified as engineers or physicists and have extensive knowledge of the medical sciences. This enables them to engage in productive and independent investigations at the interface of technology and medicine. This technology-medicine interface represents a continuum that extends from the molecular level to the whole-organism level. Accordingly, students may select from two distinct curricular sequences: cellular and molecular medicine or systems physiology and medicine.

Students in the systems physiology and medicine track are introduced to clinical medicine and become involved in the assessment and management of human disease. Students in the cellular and molecular medicine track receive in-depth training and experience in cellular and molecular biology, emphasizing the impact of modern biology on biomedical engineering. In both tracks, students learn important clinical skills and acquire a deep understanding of clinical care and medical decision-making processes.

Additionally, there are optional tracks within the MEMP program that focus on particular areas, such as neuroimaging or bioinformatics. The Bioinformatics and Integrative Genomics (BIG) program trains talented quantitative scientists in the biology, engineering, and information sciences used in genomic applications. The program features a core curriculum that focuses on engineering, biology, bioinformatics, computer science, and probability theory. A month-long introductory hands-on genomics laboratory is also an essential component of the curriculum.

MEMP applicants with undergraduate degrees in engineering or physics must apply simultaneously for admission to HST and to a graduate department at MIT or Harvard. Additional information about applying to MEMP may be obtained by contacting Ms. Catherine Modica, MIT, Room E25-518, Cambridge, MA 02139, 617-253-2307, cmodica@mit.edu.

**Medical Sciences**

HST’s Medical Sciences Program leads to the MD degree from Harvard Medical School. It is oriented toward students with a strong interest and background in quantitative science, especially in the biological, physical, and engineering, and chemical sciences. The subjects in human biology developed for this curriculum represent the joint efforts of life scientists, physicians, physical scientists, and engineers from the faculties of Harvard and MIT.

The programs of study are designed to meet the interests and needs of the individual student. The student is encouraged to pursue advanced study in areas of interest that may complement the subjects offered in the division. Such study may be undertaken as part of the MD degree requirements or may be pursued in a program that combines the MD with a master’s or doctoral degree. HST students join the students of the regular Harvard Medical School curriculum in the clinical clerkships.

Because HST is committed to educating physicians who have a deep understanding of the scientific basis of medicine and who are well equipped for an interdisciplinary research career, HST encourages students in the MD curriculum to devote time to research and requires a thesis for completion of the degree. Many MD students, however, desire even more research training than is possible during the standard four-year MD curriculum. For such students, one option is to pursue a formal PhD program in addition to an MD program. Another option expands the MD program to five or more years in order to include a major research training component. This option may lead to a master’s degree in health sciences and technology in addition to the MD degree.

The general requirements for a master’s degree at MIT are given under Graduate Education in Part 1. The subject requirements must be in addition to the minimum number of units required for the MD degree. Subjects may be chosen in scientific, technical, or clinical areas relevant to the student’s research area. Thesis research may be conducted at MIT, Harvard, or at Harvard-affiliated teaching hospitals. The completed thesis must be approved by the thesis supervisor and submitted to HST’s Graduate Committee. The master’s thesis simultaneously fulfills the thesis requirement for HST’s MD degree. The two degrees are not formally linked; the MD degree is not a prerequisite for the master’s degree.

Further details on the Medical Sciences Program and application forms may be obtained from the Office of Admissions, Harvard Medical School, 25 Shattuck Street, Boston, Massachusetts 02115. Applications must be submitted by October 15 of the year before desired matriculation. For further information, candidates can contact HST’s medical sciences admissions coordinator at hst-md-admissions@mit.edu.

**Radiological Sciences Joint Program**

The Radiological Sciences Joint Program (RSJP) offers a unique integration of engineering and physical sciences education with research opportunities in a broad spectrum of biomedical research laboratories. The RSJP doctoral program is administered in collaboration with MIT’s
Speech and Hearing Bioscience and Technology

HST’s doctoral program in Speech and Hearing Bioscience and Technology (SHBT), formerly Speech and Hearing Sciences, prepares students with an undergraduate background in science or engineering to have a broad acquaintance with the field of speech and hearing, and to develop specialized knowledge that focuses on a particular approach in research. The only program of its type in the country—and the only doctoral training program funded in this area by the National Institutes of Health—SHBT is designed to develop research scientists who can apply the concepts and methods of the physical and biological sciences to basic and clinical problems in speech and hearing using innovative research. No other research training program provides the multidisciplinary depth and breadth offered by SHBT. The four-plus-year program leads to a PhD in speech and hearing bioscience and technology from MIT. SHBT’s more than 50 participating faculty members represent 10 academic departments from Harvard and MIT, with research facilities at MIT, Harvard University, Harvard Medical School and affiliated teaching hospitals, and the Massachusetts Eye and Ear Infirmary (MEEI). The small class size of this unique program (seven to eight students per class year) ensures personalized and high-quality training by a diverse and dedicated faculty from the two institutions.

SHBT’s curriculum provides an effective method of training researchers by introducing the physical and biological bases of speech and hearing mechanisms involved in the communications process. While SHBT seeks to develop research scientists rather than clinical practitioners, there is a strong emphasis on providing students with exposure to clinical problems, approaches, and techniques. Graduates are thoroughly prepared for successful careers in basic and applied research in industry, universities, or government laboratories involved with biological and synthetic communication systems.

Typically, a student’s first two years in the program are devoted to coursework, which is supplemented by significant exposure to various research projects. Courses in the first year assume familiarity with calculus and differential equations, college-level physics, probability and statistics, and biology. The core curriculum covers the anatomical, acoustical, physiological, perceptual, and cognitive basics, as well as the clinical approaches to speech and hearing problems. The early introduction of important concepts in acoustics, anatomy, and physiology provides a solid base from which to pursue individual research interests. Early in the curriculum, students are introduced to various research laboratories that use different approaches to solving speech and hearing problems. This involvement in research provides an immediate application of classroom subjects. Students work with research advisors to develop a thorough understanding of basic concepts and tools in their fields of concentration. Later, students participate in subjects that require them to apply basic concepts to clinical problems and scientific research. Throughout the curriculum, special attention is devoted to developing personal integrity, scientific values, and scholarly practice. With faculty guidance, each student plans a concentration tailored to the student’s particular interest.

By the end of their second year, students identify an area of professional interest and choose a research project that forms the basis for their doctoral thesis. SHBT research in the speech and hearing sciences focuses on the biological and physical mechanisms underlying human communication by spoken language. The processes addressed by these sciences include the physical acoustics of sound and the perceptual neurophysiological bases of hearing, as well as the linguistic, cognitive, and motor levels of processing by talkers and listeners.

Applicants to the program should have a bachelor’s degree in physical science, biology, psychology, linguistics, communication sciences and disorders, engineering, computer science, or a related field. Superior analytical skills are strongly recommended for all applicants. Additional information may be obtained by contacting Dr. M. Christian Brown, Massachusetts Eye and Ear Infirmary, 243 Charles Street, Boston, MA 02114, 617-573-9635, mcb@epl.meei.harvard.edu.
BIOMEDICAL INFORMATICS PROGRAM

Biomedical Informatics Program

Biomedical informatics is concerned with the cognitive, information-processing, and communication tasks of medical practice, education, and research. It includes the information sciences and technology needed to support those tasks. The field is intrinsically interdisciplinary, drawing together all traditional medical disciplines, the science and technology of computing, biostatistics, epidemiology, decision sciences, and health care policy and management. In addition to a focus on clinical practice, additional areas of emphasis are in bioinformatics, and in informatics related to health services research.

HST’s predoctoral and postdoctoral training program in biomedical informatics offers fellowships to qualified US citizens or permanent residents. Several training options are offered: the Master of Science in Biomedical Informatics from HST; the PhD in Medical Computer Science from MIT’s Department of Electrical Engineering and Computer Science; the PhD in Health Decision Science in the Department of Health Policy and Management at the Harvard School of Public Health; and research fellowship training at biomedical informatics laboratories in Boston-area hospitals carried out in conjunction with the HST Biomedical Informatics Master’s Program. The master’s program is available only to HST-enrolled medical students or to students who already have advanced training in the health sciences (e.g., a doctoral degree in medicine, dentistry, nursing, veterinary medicine, clinical psychology, or a PhD in a medical relevant field such as physiology).

The combined training program offers several opportunities for education, research, and interaction among the various training sites. Course offerings at MIT and Harvard, as well as a variety of seminars, journal clubs, and other opportunities to exchange information, provide all trainees with opportunities to learn about the work at various laboratories and affiliated institutions, as well as the broader field of biomedical and health informatics.

Predoctoral fellowship applicants must concurrently apply for admission to MIT or a Harvard doctoral degree program. Postdoctoral applicants typically have at least one year and preferably three years of clinical residency before beginning their fellowship. For more information about the Biomedical Informatics Training Program, contact Dr. Robert A. Greenes, Decision Systems Group, Brigham and Women’s Hospital, 75 Francis Street, Boston, MA 02115, greenes@harvard.edu.

Clinical Investigator Training Program

The Clinical Investigator Training Program (CITP) trains postdoctoral physicians from various clinical disciplines in the techniques and processes used in patient-oriented research. Trainees develop expertise in clinical investigation while participating in an extensive educational program. The two-year program is a cooperative effort between HST, Beth Israel Deaconess Medical Center, and Pfizer, Inc. The curriculum allows trainees to develop direct experience in performing clinical investigation while, simultaneously through didactic course work, providing a strong foundation in computational and statistical sciences, biomedical ethics, the principles of clinical pharmacology, and in vivo measurement techniques, and various aspects of the drug development process.

The fellowship program consists of a primary project and core curriculum, plus an elective curriculum and a project elective. Although not required, fellows may choose to pursue a Master of Medical Sciences degree from Harvard Medical School in conjunction with CITP. The degree is awarded at the end of the two-year period upon successful completion of didactic coursework, a research project, a thesis or thesis equivalent, and a qualifying examination. CITP is open to physicians who have completed the clinical requirements for Board eligibility in their chosen specialty or subspecialty. For more information or to obtain an application, contact the CITP program coordinator, Karen Walsh, MIT, Room E18-435, 617-258-5921, kwalsh@mit.edu.

Inquiries

Additional information on degree programs, admissions, and financial aid can be obtained from HST’s Office of Academic Affairs, MIT Room E25-518, 617-258-7084.
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MIT and the Woods Hole Oceanographic Institution (WHOI) on Cape Cod offer joint doctoral degrees in oceanography and doctoral, professional, and master’s degrees in oceanographic engineering.

Graduate study in oceanography encompasses virtually all of the basic sciences as they apply to the marine environment: physics, chemistry, geology, geophysics, and biology. Applied ocean science and engineering allows for concentration in the major engineering fields of civil and environmental, mechanical, and electrical engineering.

The graduate programs administered by joint MIT/WHOI committees draw from the faculty and staff of both institutions. Students accepted to the Joint Program have access to the extensive intellectual and physical resources available for advanced study at both Woods Hole and MIT.

The Joint Program involves several departments at MIT—Earth, Atmospheric, and Planetary Sciences and Biology in the School of Science; and Civil and Environmental Engineering, Electrical Engineering and Computer Science, and Mechanical Engineering, in the School of Engineering. Financial aid, offered as research assistantships or fellowships to most entering graduate students, is sufficient to cover tuition and fees and provide a stipend. Upon admission, students register in the appropriate MIT department and at WHOI simultaneously, and are assigned academic advisors at each institution. Because the Joint Program is not affiliated with any one particular MIT department, students who wish to be considered for the program must indicate their intent on the front of their applications.

Research at WHOI is devoted to using the basic sciences and engineering to gain a better understanding of the marine environment. Some 200 scientists and engineers and a support staff of about 600 work in laboratories located in the Village of Woods Hole and on the nearby Quissett Campus. Another 75 people operate three research vessels (ranging from 177 to 279 feet in length), the deep-diving submersible ALVIN, and smaller coastal vessels. WHOI also has remotely-operated research vehicles and autonomous underwater vehicles. Computer services provided within WHOI include links to other institutions and to national networks.

A videoconference system between MIT and Woods Hole provides interactive transmission for classes. Specialized research facilities include the National Ocean Sciences Accelerator Mass Spectrometry Facility and the North-East Regional Ion Microprobe Facility. The library facilities shared with the Marine Biological Laboratory are supplemented by collections of the Northeast Fisheries Center of the National Marine Fisheries Service and the US Geological Survey’s Office of Marine Resources Branch of Atlantic Geology, all located in Woods Hole. The village is situated on the southwest corner of Cape Cod, about 80 miles from Boston.

Subjects, seminars, and opportunities for research participation are offered at both MIT and WHOI. Place of residence is determined by the student’s selected program of study and research interests, and transportation is provided between institutions. Students have the opportunity to participate in oceanographic cruises during graduate study.

The faculty of MIT, together with the WHOI scientific staff, offer a wide variety of formal and informal subjects in various aspects of oceanography and areas directly applicable to ocean science and engineering; both faculties are equally involved in all levels of instruction. The subjects are supplemented by numerous seminars, directed studies, and cross-registration privileges with Harvard, Brown, and the Boston University Marine Program. Complete listings can be found in the subject descriptions of each individual department.

Physical Oceanography
Physical oceanography is the study of the physics of the ocean. Its central goal is to describe and explain the complex motions of the ocean. Principal research areas include general circulation, air-sea interaction, shelf dynamics, mesoscale processes, and small-scale processes. The Department of Earth, Atmospheric, and Planetary Sciences offers programs in physical oceanography with WHOI, which lead to the Doctor of Science or Doctor of Philosophy degree.

Chemical Oceanography
Chemical oceanographers study the chemical composition of the marine environment and the processes that have produced the present composition of sea water and sediments. Principal research areas include water column geochemistry, sedimentary geochemistry, seawater-basalt interactions, and atmospheric chemistry. The Departments of Earth, Atmospheric, and Planetary Sciences and Civil and Environmental Engineering offer programs with WHOI in chemical oceanography and marine geochemistry. These programs lead to the Doctor of Science or Doctor of Philosophy.

Marine Geology and Geophysics
The goal of Marine Geology and Geophysics is to understand the physical and chemical processes that determine the structure and evolution of the ocean basins and their margins. Research is being conducted in a wide range of specialties including micropaleontology, paleoceanography, petrology and volcanic processes, seismology, gravity, magnetics, heat flow, sediment dynamics, and isotopic geochemistry. The Department of Earth, Atmospheric, and Planetary Sciences at MIT offers programs with WHOI in marine geology and geophysics which lead to the Doctor of Science or Doctor of Philosophy.

Biological Oceanography
Biological oceanography seeks to describe and understand the biological processes which are active in the marine and bordering environments. The research of biological oceanographers is diverse, including ecology, toxicology, biochemistry, animal behavior and physiology, and molecular biology. The programs in biological oceanography are coordinated by the Department of Biology and WHOI, and may involve research in other MIT departments such as the Department of Civil and Environmental Engineering. The programs lead to the Doctor of Science or Doctor of Philosophy.

Applied Ocean Science and Engineering
Applied ocean science and engineering involves the application of physics and the engineering sciences to the study of oceanic processes and the design of instruments, systems, and structures required to observe, measure, and work in the ocean. The Departments of Civil and Environmental Engineering, Electrical Engineering and Computer Science, and Mechanical Engineering offer joint programs with WHOI in oceanographic engineering. The programs lead to the master’s degree, engineer’s degree, Doctor of Science, or Doctor of Philosophy.
Inquiries
Application for admission to the Joint Program in Oceanography and Applied Ocean Science and Engineering with the Woods Hole Oceanographic Institution should be made on the MIT graduate application form, which may be obtained from the director of admissions at MIT or from the Academic Programs Office at WHOI. Requests for further information may be addressed to the MIT/WHOI Joint Program, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, 508-289-2219, or to the MIT Joint Program Office, Room 54-911, MIT, 617-253-7544. More information is available at http://web.mit.edu/mit-whoi/www/.