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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 2007–2008, roughly 45% of our students were women and 35% came from other countries.

Global Projects
One of MIT’s founding principles is the belief that professional competence is best fostered by focusing teaching and research on real problems in the real world, and at the School of Architecture and Planning we take that mandate very seriously.

Accordingly, a central aspect of our teaching and research is our ongoing participation in global initiatives—many of them collaborative undertakings among our five divisions, with other divisions of MIT, and with public and private institutions in the US and abroad.

As a result of this commitment, it is fair to say that the faculty and students of the school are truly citizens of the world—engaged in the problems facing countries at all stages of development, taking part in the public discussion of issues on a global scale, studying, developing and applying best practices all around the world.

We recently launched two new efforts to further strengthen the links among the School of Architecture and Planning and to the world at large: the MIT Design Laboratory, a collection of multidisciplinary teams that blur the boundaries of the specialization areas in our school; and the Urbanization Laboratory (UrbLab), a program to focus on the design and development issues posed by rapid urbanization.

In spring 2008, to enhance collaboration between the School’s divisions and with other divisions at MIT, ground was broken for a major new facility designed by Fumihiko Maki, winner of the Pritzker Prize in 1993. Adjacent to and part of the School’s legendary Media Lab, designed by alumnus I. M. Pei (1940 BArch), the facility will also house a diverse array of teaching and research efforts now going on in other divisions of the School.

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.
### Degrees Offered in the School of Architecture and Planning

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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 and humanities. 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 computer 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 area of study 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 energy-efficient technologies, building structures, materials, industrialized building systems, appropriate technology for developing countries, sustainable design, new indoor air quality, daylighting and energy efficiencies 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, a daylighting laboratory, and computer work stations. Research facilities of other departments such as Mechanical and Civil and Environmental Engineering are also used in joint research projects.

This area of study 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.

This area of study offers a concentration to undergraduates in Course 4 as well as a concentration in the Master of Science in Architecture Studies (SMArchS) program, and 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.

HTC offers a concentration to undergraduates in Course 4 and a HASS concentration and minor in the history of architecture to all MIT undergraduates. There is a doctoral program with emphasis on the history, theory, and criticism of art and architecture, and students in the Master of Science in Architecture Studies program may choose to concentrate in HTC.
The Visual Arts group offers a diverse range of subjects in studio practice. Students challenge traditional genres and push the limits imposed by gallery and museum contexts. Exploring experimental media and expanded definitions of site is encouraged. Central to the curriculum is the potential for links with programs in architecture, urbanism, technology and media studies. Related areas of research include the dialogue between art and architecture; critical approaches to public art; demarcations between public and private space; anti-monuments and new instruments of collective memory; prosthesis and extended body; nomadic design tactics; new interfaces between visual art and landscape; and performance and sound works.

This area of study 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.


### 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.
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.

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, comparative media studies, 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 and take the expected sophomore subjects. By the end of the sophomore year, the student is expected to submit to the department a proposal that enables students to concentrate on the historical, theoretical, and critical issues associated with artistic and architectural production. Introductions to the historical framework and stylistic conventions of art and architectural history 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**
- Two subjects:
  - 4.601 Introduction to Art History
  - 4.602 Modern Art and Mass Culture
  - 4.605 Introduction to the History and Theory of Architecture
  - 4.614 Religious Architecture and Islamic Cultures

**Tier II**
- Three subjects chosen from the following list, with no more than two subjects from either the history of art or the history of architecture:
  - 4.613 Civic Architecture in Islamic History
  - 4.635 Renaissance Architecture
  - 4.641 19th-Century Art
  - 4.645 Selected Topics in Architecture: 1750–Present
  - 4.651 Art Since 1940
  - 4.665 Contemporary Architecture and Critical Debate
  - 4.671 Nationalism, Internationalism, and Globalism in Modern Art
  - 4.673 Installation Art

**Tier III**
- One subject:
  - 4.609 Seminar in the History of Art and Architecture
  - Other advanced seminar in the history of art and/or architecture with permission of the HASS field advisor.

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 orient 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 areas of Building Technology, and Design and Computation.

Master of Architecture
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 70 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 3 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, 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 energy efficiency, 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 156 units of coursework (123 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, Electrical Engineering and Computer Science, and Mechanical Engineering. Research programs include energy efficiency, sustainable building design, controls, natural ventilation and indoor air quality, daylighting, masonry structures, 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, 617-253-7387, or from http://architecture.mit.edu/.

**Faculty and Staff**

**Faculty and Teaching Staff**

Yung Ho Chang, MArch
Professor of Architecture
Department Head

Leslie Keith Norford, PhD
Professor of Building Technology
MacVicar Faculty Fellow
Associate Head

**Professors**

Stanford Anderson, MArch, PhD
Professor of History and Architecture

Julian Beinart, BArch, MCP, MArch
Professor of Architecture

Michael Dennis, BArch
Professor of Architecture

Leon R. Glicksman, PhD
Professor of Building Technology
(On leave, spring)
Mark Jarzombek, DiplArch, PhD
Professor of the History and Theory of Architecture
Associate Dean, School of Architecture and Planning

Joan Jonas, MFA
Professor of Visual Arts

Caroline Jones, PhD
Professor of the History of Art

Sheila Kennedy, MArch
Professor of the Practice of Architecture

Terry Knight, PhD
Professor of Design and Computation

William J. Mitchell, MS
Professor of Architecture and Media Arts and Sciences

William Lyman Porter, MArch, PhD
Professor of Architecture without Tenure (Retired)

Nasser Rabbat, BArch, MArch, PhD
Aga Khan Professor of the History of Architecture
Director, Aga Khan Program

Adèle Naudé Santos, MAUD, MArch, MCP
Professor of Architecture and Urban Planning
Dean, School of Architecture and Planning

Anne Whiston Spirn, PhD
Professor of Landscape Architecture and Planning

George Stiny, PhD
Professor of Design and Computation

Jan Wampler, MArch
Professor of Architecture

James Wescoat, PhD
Aga Khan Professor

Krzysztof Wodiczko, MFA
Professor of Visual Arts

**Associate Professors**

Ute Meta Bauer, Dipl. of Fine Arts
Associate Professor of Visual Arts
Director, Visual Arts Program

Alexander D’Hooghe, MAUD, PhD
Class of 1922 Career Development Associate Professor of Architecture and Urbanism

Arindam Dutta, PhD
Associate Professor of the History of Architecture
(On leave, spring)

John Fernandez, MArch
Associate Professor of Architecture and Building Technology
(On leave)

David Hodes Friedman, PhD
Associate Professor of the History of Architecture

Mark Gouthorpe, BArch
Associate Professor of Design
(On leave, fall)

Rahul Mehrotra, MAUD
Associate Professor of Architecture

Takehiko Nagakura, MArch, PhD
Associate Professor of Design and Computation

John Ochsendorf, PhD
Class of 1942 Career Development Associate Professor of Building Technology

Lawrence Sass, PhD
Associate Professor of Computation and Design

Andrew Scott, BArch
Associate Professor of Architecture

Nader Tehrani, MAUD
Associate Professor of Architecture

J. Meejin Yoon, MAUD
Associate Professor of Architecture

**Assistant Professors**

Marilynne Andersen, MSc, PhD
Assistant Professor of Building Technology
(On leave, spring)

Ana Miljakić, MArch, PhD
Assistant Professor of Architecture

Kristel Smetek, PhD
Assistant Professor of the History of Art

**Visiting Professors**

Angelo Bucci, PhD (Fall)

Antonio Muntadas, MA (Spring)

**Senior Lecturer**

Shun Kanda, BArch, MArch (Spring)

**Lecturers**

Dan Chen, MArch (Fall)

Andrea Frank, MFA

Philip Freelon, MArch (Fall)

Amber Frid-Jimenez, MS (Fall)

Joe Gibbons, MFA

Bill Hubbard, Jr., MAAS

Wendy Jacob, MFA

Simon Kim, SMArchS (Fall)

Joel Lamere, MA

Jae Rhim Lee, SMViss (Fall)

Rebecca Luther, MArch (Fall)

Nondita Mehrotra, MArch

Carl Rosenberg, MArch (Spring)

Corinne Ulmann, MArch (Fall)

Angela Watson, MArch (Fall)

Joseph Zane, MFA (Fall)

**Technical Instructor**

Christopher Dewart, BA

**Research Staff**

**Principal Research Associate**

Reinhard Goethert, MArch, PhD

**Principal Research Scientist**

Kent Larson, BArch

**Research Scientist**

Stephen Intille, PhD

**Professors Emeriti**

Wayne V. Andersen, PhD
Professor of the History of Art, Emeritus

Eduardo Fernando Catalano, MArch
Professor of Architecture, Emeritus

John de Monchaux, MArch
Professor of Architecture and Urban Planning, Emeritus

Eric Dluhosch, MArch, PhD
Professor of Building Technology, Emeritus

Richard Filipowski, BA
Associate Professor of Visual Design, Emeritus

Leon Bennett Groisser, ScD
Professor of Structures, Emeritus

N. John Habraken, BI
Professor of Architecture, Emeritus

**Visiting Professors**

Angelo Bucci, PhD (Fall)

Antonio Muntadas, MA (Spring)
Edward Levine, MA, PhD
Professor of Visual Arts, Emeritus

John Randolph Myer, BArch
Professor of Architecture, Emeritus

Otto Piene, MA
Professor of Visual Design, Emeritus

Maurice Keith Smith, BArch
Professor of Architecture, Emeritus

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 Gigi Shafer, Room E15-401, 617-253-5114, fax 617-253-8542, mas@media.mit.edu.

FACULTY AND STAFF

Faculty and Teaching Staff

Mitchel Resnick, PhD
Professor of Media Arts and Sciences
LEGO Papert Career Development Professor of Learning Research
Program Head

Patricia Maes, PhD
Associate Professor of Media Technology
Associate Program Head

Professors

Neil Gershenfeld, PhD
Professor of Media Arts and Sciences

Hiroshi Ishii, PhD
Professor of Media Arts and Sciences

Tod Machover, MM
Professor of Music and Media

John Maeda, PhD
Professor of Design and Computation
Rudge (1948) and Nancy Allen Professor of Media Arts and Sciences
(On leave)

William J. Mitchell, BArch, MDes, MA
Professor of Architecture and Media Arts and Sciences

Alexander W. Dreyfoos, Jr. (1954) Professor of Media Arts and Sciences

Nicholas Negroponte, MArch
Professor of Media Technology
(On leave)

Alex Pentland, PhD
Toshiba Professor of Media Arts and Sciences

Rosalind Picard, ScD
Professor of Media Arts and Sciences

Barry Vercoe, DMA
Professor of Media Arts and Sciences

Associate Professors

Cynthia Breazeal, ScD
Associate Professor of Media Arts and Sciences

LG Career Development Professor of Media Arts and Sciences

Chris Csikszentmihályi, MFA
Associate Professor of Media Arts and Sciences

Muriel R. Cooper Career Development Professor

Judith Donath, PhD
Associate Professor of Media Arts and Sciences

Asahi Broadcasting Corporation Career Development Professor of Research in Education

Hugh Herr, PhD
Associate Professor of Media Arts and Sciences

NEC Career Development Professor of Computers and Communications

Joseph Jacobson, PhD
Associate Professor of Media Arts and Sciences

Ramesh Raskar, PhD
Associate Professor of Media Arts and Sciences

Deb Roy, PhD
Associate Professor of Media Arts and Sciences

AT&T Career Development Professor of Media Arts and Sciences

John Maeda, PhD
Professor of Design and Computation
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Joseph Jacobson, PhD
Associate Professor of Media Arts and Sciences

Ramesh Raskar, PhD
Associate Professor of Media Arts and Sciences

Deb Roy, PhD
Associate Professor of Media Arts and Sciences

AT&T Career Development Professor of Media Arts and Sciences
Joseph Paradiso, PhD
Associate Professor of Media Arts and Sciences
Sony Corporation Career Development Professor
of Media Arts and Sciences

David Small, PhD
Associate Professor of Media Arts and Sciences

**Assistant Professors**
Edward S. Boyden III, PhD
Assistant Professor of Media Arts and Sciences

Leah Beuchley, PhD
Assistant Professor of Media Arts and Sciences

**Research Staff**

**Senior Research Scientists**
Walter Bender, MSVS (On leave)
Andrew Lippman, 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 four degree programs: a Bachelor of Science in Planning; a two-year professional Master in City Planning (MCP); a one-year Master of Science in Urban Studies and Planning (usually reserved for mid-career students); and a PhD in Urban Studies and Planning. In addition, DUSP has three kinds of nondegree programs and affiliations; the Special Program in Urban and Regional Studies (for mid-career professionals from developing countries); the Community Innovators Lab (which engages mid-career professionals from communities of color in the United States and beyond); and the SENSEable City Lab, a research center concerned with the relationship between technology and cities. DUSP also offers special-student status for part-time mid-career professionals interested in taking individual subjects. Once students are admitted and enrolled at MIT, it is possible to apply for certificate programs in urban design (offered jointly with the Department of Architecture) or environmental planning.

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, regional planning, and transportation. These planning specialties can be distinguished by the geographic levels at which decision making takes place—neighborhood, city, regional, 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.

In addition, 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 private sectors. The major also provides a foundation for students who are considering graduate work in law, public policy, international development, urban design, management, and planning. The subjects in the major teach students how the tools of economics, policy analysis, political science, and urban design can be used to solve social and environmental problems in the United States and abroad. In addition, students learn the skills and responsibilities of planners who seek to promote effective and equitable social 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. In the laboratory subject, students also explore the ways emerging technology can be used to improve government decision making.

Students are encouraged to develop a program that will strengthen their 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 complete a senior project that synthesizes what they have learned. This project may consist of
an analysis of a public policy issue, a report on a problem-solving experience from an internship or other field experience, or a synthesis of research on urban affairs.

**Five-Year SB-MCP Option**

MIT undergraduate majors may apply for admission to the department's Master in City Planning (MCP) program in their junior year. Students accepted into the five-year program receive both the Bachelor of Science and the MCP at the end of five years. Admission is limited to those undergraduates who have demonstrated exceptional professional promise. Students can obtain more information on the five-year program from Sandra Welford, undergraduate administrator, Room 7-346A, 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 political government, economic, and 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. When 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, a subject that aims to synthesize past and present efforts to implement knowledge about large-scale 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></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement (can be satisfied by 11.188 in the Departmental Program)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement</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**

<table>
<thead>
<tr>
<th>Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required Subjects</strong></td>
<td>57</td>
</tr>
<tr>
<td>11.001 Introduction to Urban Design and Development, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>11.002 Making Public Policy, 12, HASS-D, CI-H</td>
<td></td>
</tr>
<tr>
<td>11.123 Big Plans, 9, HASS</td>
<td></td>
</tr>
<tr>
<td>14.01 Principles of Microeconomics, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>11.188 Urban Planning and Social Science Laboratory, 12, LAB, CI-M; permission of instructor</td>
<td></td>
</tr>
<tr>
<td><strong>Planned Electives</strong></td>
<td>57</td>
</tr>
<tr>
<td>Majors in Course 11 are required to formulate or select one stream of coursework for concentration.</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></td>
</tr>
<tr>
<td><strong>Urban and Environmental Policy and Planning</strong></td>
<td></td>
</tr>
<tr>
<td>11.011 The Art and Science of Negotiation, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>11.014 American Urban History I, 9, HASS</td>
<td></td>
</tr>
<tr>
<td>11.016 The Once and Future City, 12, HASS, CI-H</td>
<td></td>
</tr>
<tr>
<td>11.026 Downtown, 9, HASS</td>
<td></td>
</tr>
<tr>
<td>11.122 Society and Environment, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>1.011 Project Evaluation, 9</td>
<td></td>
</tr>
<tr>
<td>1.041 Engineering System Design, 12; 1.011*</td>
<td></td>
</tr>
<tr>
<td><strong>Urban Society, History, and Politics</strong></td>
<td></td>
</tr>
<tr>
<td>11.013 American Urban History I, 9, HASS</td>
<td></td>
</tr>
<tr>
<td>11.014 American Urban History II, 9, HASS</td>
<td></td>
</tr>
<tr>
<td>11.015 Riots, Strikes, and Conspiracies in American History, 12, HASS-D, CI-H</td>
<td></td>
</tr>
<tr>
<td>11.020 Poverty, Public Policy, and Controversy, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>11.023 Bridging Cultural and Racial Differences, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>11.024 Great Cities, 9, HASS</td>
<td></td>
</tr>
<tr>
<td>11.026 Downtown, 9, HASS</td>
<td></td>
</tr>
<tr>
<td>11.330 Theory of City Form, units arranged; 11.001*</td>
<td></td>
</tr>
<tr>
<td><strong>Urban and Regional Public Policy</strong></td>
<td></td>
</tr>
<tr>
<td>11.003 Methods of Public Policy Analysis, 12, HASS; 11.002, 17.30, 14.01</td>
<td></td>
</tr>
<tr>
<td>11.011 The Art and Science of Negotiation, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>11.020 Poverty, Public Policy, and Controversy, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>11.023 D-Lab: Development, 12; permission of instructor</td>
<td></td>
</tr>
<tr>
<td>11.166 Law, Social Movements, and Public Policy, 12, HASS; permission of instructor</td>
<td></td>
</tr>
<tr>
<td><strong>Urban Field Experience</strong></td>
<td></td>
</tr>
<tr>
<td>Declared majors are encouraged to take the optional urban field experience subject. 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>
<td></td>
</tr>
<tr>
<td><strong>Thesis</strong></td>
<td></td>
</tr>
<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. 11.ThT Thesis Research Design Seminar, 12, CI-M</td>
<td></td>
</tr>
</tbody>
</table>
### Departmental Program Units That Also Satisfy the GIRs

- (57)

### Unrestricted Electives

- 105

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

- 180

**Notes**

- Alternate prerequisites and corequisites are listed in the subject description.
- Course 11 majors are not permitted to have a HASS concentration in Urban Studies.
- For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.013J</td>
<td>American Urban History I</td>
</tr>
<tr>
<td>11.014J</td>
<td>American Urban History II</td>
</tr>
<tr>
<td>11.016J</td>
<td>The Once and Future City</td>
</tr>
<tr>
<td>11.020</td>
<td>Poverty, Public Policy, and Controversy</td>
</tr>
<tr>
<td>11.023</td>
<td>Bridging Cultural and Racial Differences</td>
</tr>
<tr>
<td>11.024</td>
<td>Great Cities</td>
</tr>
<tr>
<td>11.025</td>
<td>D-Lab: Development</td>
</tr>
<tr>
<td>11.026J</td>
<td>Downtown</td>
</tr>
<tr>
<td>11.029</td>
<td>Theories of Economic Development</td>
</tr>
<tr>
<td>11.122</td>
<td>Society and Environment</td>
</tr>
<tr>
<td>11.126J</td>
<td>Economics of Education</td>
</tr>
<tr>
<td>11.166</td>
<td>Law, Social Movements, and Public Policy</td>
</tr>
</tbody>
</table>

**Tier III**

- 11.123  Big Plans

### 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 dimension is the study of the methods for assessing the impacts of policy change on policy outcomes. The purpose is to provide students with a basic understanding of the range of approaches professionals use to evaluate public policies. The third dimension is an in-depth study of policymaking in one substantive field. All minors specialize in an area of public policy, such as science and technology policy, and take three subjects within that specialty. Students may also do an internship to fulfill one part of the three-subject requirement. Course 11 majors are not eligible for the public policy minor.

Students can obtain additional information from Sandra Wellford, undergraduate administrator, Room 7-346A, 617-253-9403.

More information is available from Eric Klopfer, Room 10-337, 617-253-2025.

### HASS Concentrations

DUSP offers clusters of subjects that satisfy the Institute requirement. These three-subject clusters allow students either to develop competence within a specific discipline or to explore a particular policy problem. Six areas are suggested: designing the urban environment, environmental policy, urban history, policy analysis and urban problems, legal issues and social change, and education. DUSP is currently assembling an international development cluster. Sample programs are available from Sandra Wellford, undergraduate administrator, Room 7-346A, 617-253-9403.

The DUSP concentration focusing on education can also lead to Massachusetts licensure in teaching math and science at the middle and high school levels. This requires taking 11.129, 11.130, and 11.131 in addition to the core subjects 11.124 and 11.125. More information is available from Eric Klopfer, Room 10-337, 617-253-2025.

### 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, 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. MCP students, in their application to the department, select one of these areas of specialization and, when applicable, indicate interest in the department programs in Transportation Policy and Planning, Urban Information Systems, and Regional Planning.

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 during 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 (at least three subjects, though more frequently four), 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:

- An introductory subject in the chosen specialization area, taken in the first term of the first year
- At least one core practicum subject, selected from an approved list, during the two-year program
- A thesis preparation seminar in the area of specialization, taken during the fall of the second year

Students identified as having writing issues are encouraged to take a writing course.

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 nonprofit 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, environmental justice, global environmental treaty making, environmental regulation, the role of private corporations in environmental management, brownfields redevelopment, and the mediation of environmental disputes. Students examine the interactions between built and natural systems, techniques for describing, modeling, 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’s mission is to prepare professionals with the skills and knowledge to be responsible leaders of nonprofit, governmental, and private sector organizations engaged in building equitable and sustainable urban communities, and to advance knowledge of effective and innovative policies and practices to build such communities. This mission is pursued through teaching and research based on collaboration with local people and institutions to take action to improve their communities. The planning focus encompasses 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. 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 Group** (IDG) draws on the experiences of developing and newly industrializing countries throughout the world as the basis for advice about planning at the local, regional, and national levels. IDG 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 economic development at various scales; regional planning (including decentralization); finance and project evaluation; housing, human settlements, and infrastructure services (transportation, telecommunications, water, sewage); institutions of economic growth; industrialization and industrial policies (including privatization); poverty-reducing and employment-increasing interventions, including informal sector, nongovernment organizations, and small enterprises; community, urban, and metropolitan politics and policy; property rights,
collective action, and common property issues (water, forestry, grazing, agriculture); human rights; and globalization and governance.

Urban Information Systems (UIS) is a cross-cutting group that connects faculty, staff, and students who are interested in the ways information and communication technologies impact urban planning. Research topics include building neighborhood information systems to facilitate public participation in planning; exploring the complex relationships underlying urban spatial structure, land use, transportation, and the environment; modeling urban futures and metropolitan growth scenarios; and experimenting with mobile computing, location-based services, and the community building, planning, and urban design implications of ubiquitous computing. Our Responsive City Initiative fosters interaction among students, faculty, and staff, and across research groups and projects. Through seminars and related activities, we share experiences and find ways to collaborate on the technical, planning, and social science aspects of making information technology—enabled urban futures more responsive to public and private interests in ways that are transparent and equitable.

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 information 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 under Interdepartmental Programs in the Civil and Environmental Engineering section.

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 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 a one-year Master of Science (SM) degree. The SM is intended for professionals with a number of years of distinguished practice in city planning or related fields who have a clear idea of the courses they want to take at MIT, the thesis they want to write, and the DUSP faculty member with whom they wish to work. That faculty member must be prepared to advise the candidate when at MIT and to submit a letter of recommendation so indicating as part of the candidate’s application. This process means that prior to submitting an application the candidate must contact the appropriate DUSP faculty member to establish such a relationship. The SM does not require the candidate to take the core courses, which are mandatory for MCP candidates. As indicated above, a thesis is required. 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, 617-253-5115.

Environmental Planning Certificate
Students in the MCP and PhD program who complete a specific curriculum of subjects in the Urban Studies and Planning and Architecture departments are awarded a Certificate in Environmental Planning. For further information contact the EPP office, Room 9-312, 617-253-1509.

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, professional experi-
ence, and the fit between the student’s research interests and the department’s research activities. Most successful applicants have previously completed a master’s degree.

The doctoral program emphasizes the development of research competence and flexibility in exploring questions that no single academic discipline can answer. Examples include the role of institutions in economic development and the rapid diffusion of information and communication technologies into urban planning and design. 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 qualifying 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 a field to which this discipline is applied and which coincides with the student’s research interest. Doctoral candidates are expected to complete the qualifying general examinations before beginning their third year of residence. Upon completing the qualifying general examination, a PhD candidate must write and successfully defend a doctoral dissertation that gives evidence of the capacity to do independent and innovative research.

A minimum of 72 units 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 Community Innovators Lab (CoLab) promotes social justice by expanding access to and engagement with the knowledge developed by people working on the ground in disenfranchised, low-income communities. CoLab aims to both empower and learn from those 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,” CoLab has successfully supported resident-directed change in underserved communities across the United States since 1998. Today CoLab hosts a variety of projects and guides the community-based work of up to 20 fellows each year. CoLab advances the use of practitioner and community knowledge through three strategic pathways:

- **Identifying, documenting, and organizing** practitioner and community knowledge developed through on-the-ground social justice work.
- **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.
- **Analyzing and communicating** the value and merits of practitioner and community knowledge to broad audiences.

CoLab is located in Room 7-307. Further information can be found on the CoLab website at [http://colab.mit.edu/](http://colab.mit.edu/), by emailing garythor@mit.edu, or calling 617-253-3216.

The Special Program for Urban and Regional Studies (SPURS) provides an opportunity for a small number of highly qualified mid-career professionals from developing countries. Fellows 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 de Leon, Room 9-435, 617-253-5915 or visit [http://web.mit.edu/spurs/www/](http://web.mit.edu/spurs/www/).
Paul Osterman, PhD
Nanyang Technological University Professor of Human Resources and Management

Karen R. Polenske, PhD
Professor of Regional Political Economy and Planning

Martin Rein, MSW, PhD
Professor of Social Policy

Bishwapriya Sanyal, MCP, PhD
Ford International Professor of Urban and Regional Planning
Director, Special Program for Urban and Regional Studies in Developing Countries
Chair, MIT Faculty

Anne Spirn, MLA
Professor of Landscape Architecture and Planning
(On leave, spring)

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

Lorlene Hoyt, PhD
Associate Professor of Technology and Planning
(On leave, fall)

Eric Klopper, PhD
Associate Professor of Education
Director, Teacher Education Program

Judith Layzer, PhD
Edward H. and Joyce Linde Career Development Associate Professor of Environmental Policy
Chair, Undergraduate Program
(On leave, fall)

Balakrishnan Rajagopal, SJD
Associate Professor of Law and Development

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

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

Michael Flaxman, PhD
Charles H. and Ann Spaulding Career Development Assistant Professor of Urban Technologies and Information Systems

Annette Kim, PhD
Ford Career Development Assistant Professor of Urban and Regional Planning
(On leave, fall)

P. Christopher Zegras, PhD
Ford Career Development Assistant Professor of Urban Planning and Transportation
(On leave, spring)

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

Terry Szold, MRP
Adjunct Associate Professor of Land Use Planning

Karl Seidman, MPP

Cherie Abbanat, MCP
Anne Beamish, PhD

Ezra Glenn, MA, AICP
Christopher Gordon, MS
YuHung Hong, PhD
Aseem Inam, PhD
John Kennedy, MS
John Macomber, MBA
W. Tod McGrath, MBA
Gary McKissick, PhD
Harvey Michaels, MCP
James Pennington, MSRED
Jonathan Raab, PhD
Gloria Schuck, PhD
Susan Silberberg-Robinson, MCP
Yanni Tsipis, MS

Principal Research Scientists
Christie Baxter, PhD
Thomas Piper, MArch

Visiting Faculty and Scholars
Dolores Acevedo-Garcia, PhD
MLK Visiting Associate Professor

Manuel Castells, PhD
Distinguished Visiting Professor of Sociology and Planning

Lois Craig, BA
Visiting Senior Lecturer

Lorenzo Goette, PhD
Visiting Assistant Professor

Herman Karl, PhD
Visiting Lecturer

Donyun Kim, PhD
Visiting Associate Professor

Sam Bass Warner, PhD
Visiting Professor of Urban History

Professors Emeriti
John de Monchaux, MArch
Professor of Architecture and Planning, Emeritus

Bernard J. Frieden, MCP, PhD
Ford Professor of Urban Development, Emeritus

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.
Technology’s enormous influence on society has created a large demand for engineering graduates, not only in the professional practice of engineering, but also in bringing 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.

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.

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 freshmen to engineering. 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 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 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 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—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 an educational initiative whose mission is to recognize outstanding inventors as role models, encourage sustainable new solutions to real-world problems, and enable and inspire youth to pursue creative lives and careers through invention. It accomplishes this through annual awards, grants, and outreach activities, including the prestigious $500,000 Lemelson-MIT Prize, $100,000 Lemelson-MIT Award for Sustainability, and $30,000 Lemelson-MIT Student Prize. Lemelson-MIT InvenTeams is the program’s national initiative to inspire a new generation of inventors among high school students through grants that support a noncompetitive, team-based approach to learning and problem solving.

The latest addition to the School of Engineering is its Office of Professional Education Programs (PEP), created in 2002 from the Center for Advanced Educational Services (formerly the Center for Advanced Engineering Study) and the 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 eight academic departments and one division 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. Almost 60 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 way their individual disciplines are applied. Interdepartmental centers, laboratories, and programs provide opportunities for faculty, students, and research staff 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.

School-Wide Electives

The School of Engineering also offers a set of School-Wide Elective (SWE) subjects. An SWE 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 also be the interface between an academic program in the School of Engineering and a program in another School at MIT; it may be a service subject to engineering students and other students; and it may be germane to many engineering students without being central to any one departmental program. Please note that registration for SWE 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:**

- Introduction to Modeling and Simulation
- Inventions and Patents
- Management in Engineering
- UPOP IAP Workshop
- UPOP Summer Practice Experience
- UPOP Reflective Learning Experience

**Graduate SWE subjects include:**

- Applications 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

**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 Edward Crawley is the faculty director. Open to all School of Engineering sophomores, this innovative program aims to provide all engineering students with an opportunity to appreciate engineering practice outside the academic context through experiential learning that emphasizes the professional awareness, skills, and attitudes required to thrive in the world of engineering work. UPOP has four components: an intensive one-week engineering practice workshop offered during IAP; extensive individual coaching and several pre-employment workshops taught during the sophomore fall and spring terms; 10 to 12 weeks of meaningful summer employment; and, in the following fall, a series of written and oral reflection exercises, including 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 and professional skills: effective application of technical knowledge, cross-cultural communication, teamwork, leadership, and self-understanding. The curriculum has been designed to be highly interactive, involving students in case studies, simulations, and role-play exercises. Teams of seven to nine students are assigned instructor-mentors who guide them through the faculty-led program. Students receive three units of academic credit upon successful completion of the course.

The UPOP Summer Practice Experience exposes students to the entire job cycle, from resume submission through interviews, negotiating terms, accepting a position, declining offers gracefully, to the actual hands-on work experience. The UPOP staff facilitate the matching of students with employers, placing them in traditional companies, start-up ventures, nonprofit organizations, and government agencies. Students keep journals during their internship, recording observations and making cognitive links to concepts taught in the UPOP curriculum. The summer internship includes a site visit by UPOP faculty or staff and is followed by a reflection and assessment program back on campus. 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 can be obtained from the Engineering department in which the student is registered or from Susann Luperfoy, executive director, Undergraduate Practice Opportunities Program, Room 12-193, 617-253-0055, fax 617-253-8457, luperfoy@mit.edu, or [http://web.mit.edu/engineering/upop/](http://web.mit.edu/engineering/upop/).
Degrees Offered in the School of Engineering

### Aeronautics and Astronautics  Course 16

<table>
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<tr>
<th>Degree</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>SB</td>
<td>Aerospace Engineering</td>
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<tr>
<td>SB</td>
<td>Aerospace Engineering with Information Technology</td>
</tr>
<tr>
<td>SM</td>
<td>Aeronautics and Astronautics</td>
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<tr>
<td>SM/MBA</td>
<td>Engineering/Management—dual degree with Leaders for Manufacturing Program</td>
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<tr>
<td>Engineer</td>
<td>Aeronautics and Astronautics</td>
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<tr>
<td>PhD, ScD</td>
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<td>PhD, ScD</td>
<td>Aerospace Computational Engineering</td>
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<td>PhD, ScD</td>
<td>Air-Breathing Propulsion</td>
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<td>PhD, ScD</td>
<td>Aircraft Systems Engineering</td>
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<td>PhD, ScD</td>
<td>Air Transportation Systems</td>
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<td>PhD, ScD</td>
<td>Autonomous Systems</td>
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<td>PhD, ScD</td>
<td>Communications and Networks</td>
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<td>PhD, ScD</td>
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<td>PhD, ScD</td>
<td>Humans in Aerospace</td>
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<tr>
<td>PhD, ScD</td>
<td>Materials and Structures</td>
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<td>PhD, ScD</td>
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<td>Space Systems</td>
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### Biological Engineering  Course 20

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<td>Biological Engineering</td>
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<td>SM</td>
<td>Toxicology</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>Biomedical Engineering</td>
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<td>PhD, ScD</td>
<td>Applied Biosciences</td>
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<td>Bioengineering</td>
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<td>PhD, ScD</td>
<td>Genetic Toxicology</td>
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<tr>
<td>PhD, ScD</td>
<td>Molecular and Systems Bacterial Pathogenesis</td>
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<td>PhD, ScD</td>
<td>Molecular and Systems Toxicology and Pharmacology</td>
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<td>PhD, ScD</td>
<td>Molecular Systems Toxicology</td>
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<td>Toxicology</td>
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### Chemical Engineering  Course 10

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<th>Course Title</th>
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<tbody>
<tr>
<td>SB</td>
<td>Chemical Engineering</td>
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<td>SB</td>
<td>Chemical-Biological Engineering</td>
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<td>SM</td>
<td>Chemical Engineering</td>
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<td>SM</td>
<td>Chemical Engineering Practice</td>
</tr>
<tr>
<td>SM/MBA</td>
<td>Engineering/Management—dual degree with Leaders for Manufacturing Program</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Chemical Engineering</td>
</tr>
<tr>
<td>PhD</td>
<td>Chemical Engineering Practice</td>
</tr>
</tbody>
</table>

### Civil and Environmental Engineering  Course 1

<table>
<thead>
<tr>
<th>Degree</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>SB</td>
<td>Environmental Engineering Science</td>
</tr>
<tr>
<td>SM</td>
<td>Civil and Environmental Engineering</td>
</tr>
<tr>
<td>SM/MBA</td>
<td>Engineering/Management—dual degree with Leaders for Manufacturing Program</td>
</tr>
<tr>
<td>MEng</td>
<td>Civil and Environmental Engineering</td>
</tr>
<tr>
<td>Civil Engineer</td>
<td>Civil and Environmental Engineering</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Biological Oceanography (jointly with WHOI)</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Chemical Oceanography (jointly with WHOI)</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Civil and Environmental Engineering</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Civil and Environmental Systems</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Coastal Engineering</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Construction Engineering and Management</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Environmental Biology</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Environmental Chemistry</td>
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<tr>
<td>PhD, ScD</td>
<td>Environmental Engineering</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Environmental Fluid Mechanics</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Geotechnical and Geoenvironmental Engineering</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Hydrology</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Information Technology</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Oceanographic Engineering (jointly with WHOI)</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Structures and Materials</td>
</tr>
<tr>
<td>PhD, ScD</td>
<td>Transportation</td>
</tr>
</tbody>
</table>
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 Science and Engineering
MEng Electrical Engineering and Computer Science
SM Electrical Engineering and Computer Science
SM/MBA Engineering/Management—dual degree with Leaders for Manufacturing Program

Electrical Engineer
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 and Management—jointly offered with the Sloan School of Management through the System Design and Management Program
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

Materials Engineer
Metallurgical Engineer
PhD, ScD Archaeological Materials
PhD, ScD Bio- and Polymeric Materials
PhD, ScD Electronic, Photonic, and Magnetic Materials
PhD, ScD Emerging, Fundamental, and Computational Studies in Materials Science
PhD, ScD Materials Science and Engineering
PhD, ScD Structural and Environmental Materials

Mechanical Engineering  Course 2
SB Engineering
SB Mechanical and Ocean Engineering
SB Mechanical Engineering
SM Mechanical Engineering
SM Naval Architecture and Marine Engineering
SM Ocean Engineering
SM Oceanographic Engineering (jointly with WHOI)
SM/MBA Engineering/Management—dual degree with Leaders for Manufacturing Program
MEng Manufacturing

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
SB Nuclear Science and Engineering
SM Nuclear Science and Engineering

Nuclear Engineer
PhD, ScD Nuclear Science and Engineering

Polymer Science and Technology
PhD Polymer Science and Technology

Notes
Many departments make it possible for a graduate student to pursue a simulta-
neous 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 students, faculty, and staff in the Department of Aeronautics and Astronautics (Aero-Astro) share a passion for air and space vehicles, the technologies that enable them, and the missions they fulfill.

Aerospace is an intellectually challenging, economically important, and exciting field, offering unique opportunities for students and researchers to contribute to the future of exploration, transportation, communication, and security. The department’s mission is to prepare engineers for success and leadership in the conception, design, implementation, and operation of aerospace and related engineering systems. It achieves this through its commitment to educational excellence, and to the creation, development, and application of the technologies critical to aerospace vehicle and information engineering, and the architecture and engineering of complex high-performance systems.

The department has a tradition of both strong scholarship and of contributing to the solution of “industrial-strength” problems. Its reach within aerospace extends to high levels of policy and practice. The Aero-Astro community includes a former space shuttle astronaut, a former secretary of the Air Force, two former NASA associate administrators, three former Air Force chief scientists, 12 members of the National Academy of Engineering, and 16 fellows of the American Institute of Aeronautics and Astronautics. Several members of the department have served as executives in the aerospace industry and have even founded companies.

Several years ago, working closely with its student, alumni, industry, government, and academic stakeholders around the world, Aero-Astro developed and implemented a landmark educational initiative for its degree programs, known as CDIO. The CDIO initiative reflects the department’s belief that its graduates must be knowledgeable in all phases of the aerospace system life cycle: conceiving, designing, implementing, and operating. The department adopted a new form of undergraduate engineering education, motivating its students to master a deep working knowledge of the technical fundamentals while giving them the skills, knowledge, and attitudes necessary to lead in the creation and operation of products, processes, and systems. In addition, it reformed its teaching methods, redesigned its curriculum, and performed a $20 million state-of-the-art reconstruction of its teaching laboratories. Aero-Astro’s academic program and facilities now serve as models for 30 engineering schools on four continents.

The reconstruction of the teaching laboratories was manifested in the creation of the Learning Laboratory for Complex Systems. The Learning Laboratory provides enhanced opportunities for hands-on learning experiences closely integrated with the department’s curriculum. The Learning Lab’s Arthur Gelb Laboratory features a modern machine shop, composites fabrication facility, electronics design lab, and large team projects area with equipment for student projects. The Robert C. Seamans Jr. Laboratory is a community study area with meeting and discussion rooms, an extensively IT-equipped design/conference room, and a comprehensive aerospace library. The Design Studio, which replicates facilities at major aerospace companies, provides IT and software resources to support concurrent team engineering sessions and distance learning. The Gerhard Neumann Hangar includes low-speed and supersonic wind tunnels, computers equipped with flight simulation applications, engineering hardware displays, and workspace for large-scale student projects.

Aero-Astro students, faculty, and staff work with each other, with colleagues across MIT, and with institutions around the world. These linkages enable them to tackle challenging multidisciplinary problems and to amplify their contributions. As a result, the department is connected, busy, global, hectic, open, collegial, and fun. Faculty and students are engaged in hundreds of research projects under the auspices of the department’s laboratories and centers. Many research activities in other MIT laboratories and centers are open to Aero-Astro students as well. See the Research Laboratories and Activities section below for more information.

Graduates with an aerospace engineering degree find careers in commercial and military aircraft and spacecraft engineering, space exploration, air- and space-based telecommunication industries, teaching, research, military service, and related technology-intensive fields such as transportation, information, and the environment. The comprehensive technical education, with its strong emphasis on understanding complex systems, is also excellent preparation for careers in business, law, medicine, and public service.

In looking toward future challenges and opportunities in the aerospace field, the department has identified eight areas in which it is committed to building and strengthening its ability to make important contributions: space exploration; autonomous systems; environment; communications and networks; computation, design, and simulation; air transportation; large-scale complex systems; and advancing engineering education. By striving for excellence in the underlying core disciplines and emphasizing the collaborative problem solving required for tackling the complex, multidisciplinary problems that characterize this industry, Aero-Astro is positioning itself to respond to these and future opportunities and challenges.

**Sectors of Instruction**

The department’s faculty are organized into three sectors of instruction. Typically, a faculty member teaches both undergraduate and graduate subjects in one or more of the sectors.

**Information Sector**

Most of the aerospace systems of the future will either revolve around or critically depend upon information technology, and all will exploit IT 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 subsystems 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.

Faculty members in the Information Sector teach and perform research on a broad range of areas, including 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 on 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 with 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 who contribute to 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 trade-offs 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 Advancement 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 are responsible for teaching and research in the fields of computation, fluid mechanics, propulsion, materials, and structures—technologies needed for the design of aerospace vehicles. Although these can be considered disciplinary fields, the faculty emphasize interdisciplinary approaches in their teaching and research.

The intellectual breadth of the sector spans activities ranging from fundamental engineering science to design techniques, measurement technology, and 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; structural dynamic analysis and control; turbomachinery; robust design of propulsion and energy system components; electric and chemical space propulsion; gas turbine engine design; advanced composites, including nanoscale synthesis, characterization, and modeling; propulsion system integration; aerospace noise, emissions, and environmental impact; microelectromechanical systems and materials; multiscale modeling and simulation of advanced materials: engineered materials, failure mechanisms, and structural health monitoring; and biofluid mechanics.

Research laboratories and large interdisciplinary projects affiliated with the sector include the Aerospace Computational Design Laboratory; FAA/NASA Center of Excellence: Partnership for Air Transportation Noise and Emissions Reduction; Gas Turbine Laboratory; Nano-Engineered Composite Aerospace Structures Consortium; Space Propulsion Laboratory; and 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 program is designed to prepare the graduate for an entry-level position in the aerospace field and for further education at the master’s level. The program includes an opportunity for a year’s study abroad.

The CDIO of aerospace and related complex high performance systems and products forms the engineering context of the department’s educational program. The skills and attributes emphasized go beyond the formal classroom curriculum and include: modeling, design, the ability for self education, computer literacy, communication and teamwork skills, ethics, 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.

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.

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 the subjects 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 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 the subjects 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.

### Bachelor of Science in Aerospace Engineering/Course 16-1

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

<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</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement [can be satisfied from among 1.001; 6.041; 18.03 or 18.034; and 16.001 in the Departmental Program]</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement [can be satisfied by 16.622, 16.821, or 16.831/16.832 in the Departmental Program]</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></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). See the Laboratory and Capstone section below for specific options.

### PLUS Departmental Program

<table>
<thead>
<tr>
<th>Subject names below are followed by credit units, and by prerequisites, if any (corequisites in italics)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Departmental Core</strong> (Required for students in both degree programs)</td>
<td>108</td>
</tr>
<tr>
<td>16.001 Unified Engineering I, 12; REST; Physics II (GIR), 18.03*, Chemistry (GIR)</td>
<td></td>
</tr>
<tr>
<td>16.002 Unified Engineering II, 12; Physics II (GIR), 18.03*, Chemistry (GIR)</td>
<td></td>
</tr>
<tr>
<td>16.003 Unified Engineering III, 12; 16.001, 16.002</td>
<td></td>
</tr>
<tr>
<td>16.004 Unified Engineering IV, 12; 16.001, 16.002</td>
<td></td>
</tr>
<tr>
<td>1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; Calculus I (GIR)</td>
<td></td>
</tr>
<tr>
<td>16.06 Principles of Automatic Control, 12; 16.004, 16.07</td>
<td></td>
</tr>
<tr>
<td>16.07 Dynamics, 12; 16.004, 16.06</td>
<td></td>
</tr>
<tr>
<td>6.041 Probabilistic Systems Analysis, 12, REST; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GIR) or 18.034 Differential Equations, 12, REST; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td><strong>Professional Area Subjects</strong></td>
<td>at least 48</td>
</tr>
</tbody>
</table>

All students must take at least 48 units from among the subjects designated by the department as Professional Area Subjects. The program must include subjects from at least three professional areas. Students in Course 16-1 must take at least 24 units from the Professional Area Subjects in Aerospace Engineering. Students in Course 16-2 must take at least 36 units from among the Professional Area Subjects in Aerospace Information Technology.

**Aerospace Engineering, 16-1**

- **Fluid Mechanics**
  - 16.100 Aerodynamics, 12; 16.004
- **Materials and Structures**
  - 16.20 Structural Mechanics, 12; 16.004
- **Propulsion**
  - 16.50 Introduction to Propulsion Systems, 12; 16.004*
- **Computational Tools**
  - 16.90 Computational Methods in Aerospace Engineering, 12; 16.004*; 6.041

**Aerospace Information Technology, 16-2**

- **Estimation and Control**
  - 16.30 Estimation and Control of Aerospace Systems, 12; 16.06*
- **Computer Systems**
  - 6.111 Introductory Digital Systems Lab, 12; 16.004*
  - 16.35 Real-Time Systems and Software, 12; 1.00*
- **Communications Systems**
  - 16.36 Communication Systems Engineering, 12; 16.004*, 6.041
- **Humans and Automation**
  - 16.400 Human Factors Engineering, 12; 16.06
  - 16.410 Principles of Autonomy and Decision Making, 12; 1.00*
Laboratory and Capstone Subjects

One of the following two subjects:
16.82 Flight Vehicle Engineering, 12, CI-M; permission of department
16.83 Space Systems Engineering, 12, CI-M; permission of department

Plus one of the following three sequences:
Experimental Projects
16.621 Experimental Projects I, 6; 16.06, 16.07
16.622 Experimental Projects II, 12, LAB, CI-M; 16.621, 6.041
or
Flight Vehicle Development
16.821 Flight Vehicle Development, 18, LAB, CI-M; 16.82
or
Space Systems Development
16.831 Space Systems Development I, 12, LAB, CI-M; 16.83
16.832 Space Systems Development II, 6, LAB; 16.831

Departmental Program Units That Also Satisfy the GIRs

Unrestricted Electives

(36)

Total Units Beyond the GIRs Required for SB Degree

48

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 and corequisites 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 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 CDIO context of the Aero-Astro curriculum. They also satisfy the Institute requirement as Communication-intensive in the Major (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 Engineering Design and Rapid Prototyping, offered during the Independent Activities Period, and 16.812 The Aerospace Industry, offered in the spring term.

Double Major Program

Students may pursue two majors under the Double Major 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 major 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, marie@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, nonprofit 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 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), L‘Institut Supérieur de l’Aéronautique et de l’Espace (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 also participates in the Cambridge University–MIT Undergraduate Exchange (CME) program. Students enroll in the academic cycle of the host institution and take courses in the local language. They 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 (MASC) in partnership with Amherst College, Boston University, Harvard University, College of the Holy Cross, Holyoke Community College, Mount Holyoke College, Northeastern University, The Olin College of Engineering, Roxbury Community College, Smith College, Tufts University, University of Massachusetts, Wellesley College, Williams College, Worcester College, Worcester Polytechnic Institute, Boston Museum of Science, the Marine Biological Laboratory, the Christa McAuliffe Center/Framingham College, and many aerospace companies and laboratories throughout the United States. 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, support for student travel to present conference papers, a January internship at the Kennedy Space Center, a spring undergraduate seminar on modern space science and engineering, an annual public lecture by a distinguished member of the aerospace community, and summer workshops for precollege teachers. An important function of the program is coordinating placement of students in summer positions in industry and at NASA centers for summer academies and research opportunities. For more information, contact the program coordinator, Massachusetts Space Grant Consortium, Room 33-208, 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, 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 others 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. Detai led 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 also must submit the Graduate Record Examination (GRE) test results.
New graduate students are normally admitted as candidates for the degree of Master of Science. Admission to the doctoral program is offered to students who have been accepted for graduate study through a three-step process:

1. Passing performance on the field examination (FE). The standard for passing the FE is the demonstration of superior intellectual ability through skillful use of concepts, including synthesis of multiple concepts, in foundational, graduate-level material in a field of aerospace engineering.

2. Passing performance on the research evaluation (RE). The standard for passing the RE is the demonstration of a superior ability to solve research-oriented problems, with guidance, in a field relevant to aerospace engineering.

3. Granting of admission to the doctoral program through a faculty review consisting of an examination of the student’s achievements, including an assessment of the quality of past research work and evaluation of the student’s academic record in light of the performance on the FE and RE.

The FE and RE 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 FE and RE 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 or, in some cases, in the spring term of the first year of the 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.

**Degree Requirements**

All entering students are provided with additional information concerning degree requirements, including lists of recommended subjects, thesis advising, research and teaching assistantships, and course and thesis registration.

**Degrees Offered**

**Master of Science in Aeronautics and Astronautics**

The Master of Science (SM) degree is a one- to two-year graduate program with a beginning research or design experience represented by the SM thesis. This degree prepares the graduate for an advanced position in the aerospace field, and provides a solid foundation for future doctoral study.

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 completed before admission to the program. Students holding research assistantships typically require a longer period of residence.

In addition, the department’s SM program requires 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.

**Doctor of Philosophy and Doctor of Science**

Aero-Astro offers doctoral degrees (PhD and ScD) that emphasize in-depth study, with a significant research project in a focused area. Admission to the doctoral program requires students to pass a graduate-level examination in a field of aerospace engineering as well as to demonstrate an ability to conduct field research. The doctoral degree is awarded after completion of an individual course of study, submission and defense of a thesis proposal, and submission and defense of a thesis embodying an original research contribution.

The general requirements for this degree are given in the section on General Degree Requirements for graduate education in Part 1. A detailed description of the program requirements are outlined in a booklet entitled The Doctoral Program, available on the department website. After successful admission to the doctoral program, the doctoral candidate selects a field of study and research in consultation with the thesis supervisor and forms a doctoral thesis committee, which assists in the formulation of the candidate’s research and study programs.
and monitors his or her progress. Demonstrated competence for original research at the forefront of aerospace engineering is the final and main criterion for granting the doctoral degree. The candidate’s thesis serves in part to demonstrate such competence and, upon completion, is defended orally in a presentation to the faculty of the department, who may then recommend that 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 through the Bioastronautics PhD program offered as part of the Medical Engineering and Medical Physics PhD program in the Harvard-MIT Division of Health Sciences and Technology (HST) or in conjunction with the PhD and MEng programs in the Department of Biological Engineering (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) program offers a master’s degree to students interested in the analysis and application of computational approaches to designing and operating engineered systems. The curriculum is designed with a common core serving all engineering disciplines and an elective component focusing on specific applications. Current MIT graduate students may pursue a CDO master’s degree in conjunction with a department-based master’s or PhD program. For more information, see the full program description under Interdisciplinary Graduate Programs or visit [http://web.mit.edu/cdo-program/index.html](http://web.mit.edu/cdo-program/index.html).

**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 from a participating engineering department. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description under Engineering Systems Division or visit [http://lfm.mit.edu/](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 under Engineering Systems Division or visit [http://sdm.mit.edu/](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 under Engineering Systems Division or visit [http://tppserver.mit.edu/](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, contact Marie Stuppard, mas@mit.edu. For information concerning admissions, financial aid and assistantships, 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 Decisions 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 Controls Laboratory
The Aerospace Controls Laboratory (ACL) researches topics related to autonomous systems and control design for aircraft, spacecraft, and ground vehicles. Theoretical research is pursued in areas such as decision making under uncertainty; path planning, activity, and task assignment; estimation and navigation; sensor network design; and robust control, adaptive control, and model predictive control. A key part of ACL is RAVEN (Real-time Indoor Autonomous Vehicle Test Environment), a unique experimental facility that uses motion-capture sensing to enable rapid prototyping of flight controllers for helicopters and aircraft; robust coordination algorithms for multiple helicopters; and vision-based sensing algorithms for indoor flight.

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 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 propulsive 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 complex acquisition displays, human supervisory control of multiple heterogeneous unmanned vehicles; and developing and applying metrics for human supervisory systems.
International Center for Air Transportation

The mission of ICAT is to contribute to improving the safety, efficiency, environmental performance, 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 Advancement Initiative

The Lean Advancement Initiative (LAI) at MIT, together with its Educational Network, offers its 63 organizational members from industry, government, and academia the newest and best thinking, products, and tools related to lean enterprise transformation. A unique and powerful research consortium, LAI provides a neutral forum for sharing research findings, lessons learned, and best practices. LAI’s work is designed to enable enterprises to effectively, efficiently, and reliably create value in complex and rapidly changing environments. LAI enables the focused and accelerated transformation of complex enterprises through collaborative stakeholder engagement in developing and institutionalizing principles, processes, behaviors, and tools for enterprise excellence. 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 spaceflight 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. This includes multiscale modeling and simulation of the mechanics of advanced materials used in the aerospace industry. Recently, the focus of the laboratory has broadened into other areas including nano-engineered hybrid advanced composite design, fabrication, and testing; carbon-nanotube-based nanocomposite synthesis, characterization, and modeling; 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 210-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.

Faculty and Staff

Faculty and Teaching Staff

Ian Anton Waitz, PhD
Jerome C. Hunsaker Professor of Aeronautics and Astronautics

MacVicar Faculty Fellow
Department Head

David Louis Darmofal, PhD
Associate Professor Aeronautics and Astronautics

MacVicar Faculty Fellow
Associate Department Head

Professors

Edward Francis Crawley, ScD
Ford Professor of Aeronautics and Astronautics and Engineering Systems

John Jacob Deyst, Jr., ScD
Professor of Aeronautics and Astronautics

Mark Drela, PhD
Professor of Aeronautics and Astronautics

Terry J. Kohler Professor of Fluid Dynamics
Alan Harry Epstein, PhD
Richard Cockburn Maclaurin Professor of Aeronautics and Astronautics
Edward Marc Greitzer, PhD
H. N. Slater Professor of Aeronautics and Astronautics
Steven Ray Hall, ScD
Professor of Aeronautics and Astronautics
MacVicar Faculty Fellow
Robert John Hansman, Jr., PhD
T. Wilson Professor of Aeronautics and Astronautics and Engineering Systems
Wesley L. Harris, PhD
Charles Stark Draper Professor of Aeronautics and Astronautics
Associate Provost for Faculty Equity
Daniel Edgar Hastings, PhD
Professor of Aeronautics and Astronautics and Engineering Systems
Dean for Undergraduate Education
Jeffrey Alan Hoffman, PhD
Professor of the Practice of Aeronautics
Jonathan Patrick How, PhD
Professor of Aeronautics and Astronautics
Paul Alfred Lagacé, PhD
Professor of Aeronautics and Astronautics and Engineering Systems
Nancy Gail Leveson, PhD
Professor of Aeronautics and Astronautics and Engineering Systems
Robert Liebeck, PhD
Professor of the Practice of Aerospace Engineering
Manuel Martínez-Sánchez, PhD
Professor of Aeronautics and Astronautics
David W. Miller, ScD
Professor of Aeronautics and Astronautics
Dava Jean Newman, PhD
Professor of Aeronautics and Astronautics and Engineering Systems
MacVicar Faculty Fellow
Director, Technology and Policy Program
Deborah J. Nightingale, PhD
Professor of the Practice of Aeronautics and Astronautics and Engineering Systems
Amedeo Rodolfo Odoni, PhD
Professor of Aeronautics and Astronautics and Civil and Environmental Engineering
Jaume Peraire, PhD
Professor of Aeronautics and Astronautics
Sheila Evans Widnall, ScD
Professor of Aeronautics and Astronautics and Engineering Systems
Institute Professor
Brian Charles Williams, PhD
Professor of Aeronautics and Astronautics
Laurence Retman Young, ScD
Apollo Program Professor of Astronautics
Professor of Health Sciences and Technology

Associate Professors
M. L. Cummings, PhD
Associate Professor of Aeronautics and Astronautics and Engineering Systems
Olivier Ladislas de Weck, PhD
Associate Professor of Aeronautics and Astronautics and Engineering Systems
Emilio Frazzoli, PhD
Associate Professor of Aeronautics and Astronautics
Eytan Modiano, PhD
Associate Professor of Aeronautics and Astronautics
Raúl Alberto Radovitzky, PhD
Associate Professor of Aeronautics and Astronautics
Zoltan Sandor Spakovszky, PhD
H. N. Slater Associate Professor of Aeronautics and Astronautics
Karen Elizabeth Willcox, PhD
Associate Professor of Aeronautics and Astronautics
Moe Win, PhD
Associate Professor of Aeronautics and Astronautics

Assistant Professors
Hamsha Balakrishnan, PhD
T. Wilson Assistant Professor of Aeronautics and Astronautics and Engineering Systems

Paul Cesar Lozano, PhD
Charles Stark Draper Assistant Professor of Aeronautics and Astronautics
Youssef Marzouk, PhD
Boeing Assistant Professor of Aeronautics and Astronautics
Nicholas Roy, PhD
Assistant Professor of Aeronautics and Astronautics
Brian L. Wardle, PhD
Assistant Professor of Aeronautics and Astronautics
Annalisa Lynn Weigel, PhD
Jerome C. Hunsaker Assistant Professor of Aeronautics and Astronautics and Engineering Systems

Visiting Faculty
Nicholas Cumpsty, PhD
Leonard Daniel, PhD
I. Kristina Lundqvist, PhD
Raymond J. Sedwick, PhD

Visiting Scientists/Engineers
Tomoki Kawakubo, MEng
Seung-hyun Kim, PhD

Senior Lecturers
Richard Horace Battin, PhD
Fredric Franklin Ehrich, ScD
John E. Keese, MS, Colonel USAF (Ret)
Richard B. Lewis II, MS
Charles McMaster Oman, PhD
Rudrapatna V. Ramnath, PhD

Lecturers
Peter Paul Belobaba, PhD
Doris R. Brodeur, PhD
Brian N. Nield, MS
George Thomas Schmidt, ScD
David J. Willis, PhD

Academic Staff
Diane Hauer Soderholm, PhD

Technical Instructors
Todd R. Billings
Richard Frank Perdichizzi
David Robertson
Research Staff

Senior Research Engineers
Charles McMaster Oman, PhD
Choon Sooi Tan, PhD

Principal Research Engineers
Gerald Roger Guenette, Jr., PhD
Robert Haines, MS
Stuart Jacobson, PhD

Principal Research Scientists
Oleg V. Batishehev, PhD
Peter Paul Belobaba, PhD

Research Engineers
Yifang Gong, PhD
James Hileman, PhD
Joseph A. Palladino, PhD
Alvar Saenz-Otero, PhD

Research Scientists
Woo Sik Kim, PhD
Antonio Miravete, PhD
Alan Natapoff, PhD
David J. Willis, PhD

Research Specialists
Paul Henry Bauer, BS
John J. Kane, Jr., BS
James M. Letendre

Postdoctoral Associates
Jacob Crandall, PhD
Birsen Donmez, PhD
Nicholas Dulac, PhD
Hai Minh Duong, PhD
Hyang Won Lee, PhD
Ngoc Cuong Nguyen, PhD
Afreen Siddiqi, PhD
James M. A. Waldie, PhD

Research Affiliates
Paul Jon Cefola, PhD
Javier de Luis, PhD
Dov Dori, PhD
James Stark Draper, PhD
Heiko Hecht, PhD
Michel Ingham, PhD
Joakim Karlsson, PhD
Ali Merchant, PhD
Richard Miake-Lye, PhD

James Donald Paduano, PhD
Martinus Van Schoor, PhD
Conrad Wall, III, PhD
Gregory Leon Zacharias, PhD

Professors Emeriti
Eugene Edzards Covert, ScD
T. Wilson Professor of Aeronautics and Astronautics, Emeritus
John Dugundji, ScD
Professor of Aeronautics and Astronautics, Emeritus
Shaoul Ezekiel, ScD
Professor of Aeronautics and Astronautics and Electrical Engineering, Emeritus
Robert Louis Halfman, SM
Professor of Aeronautics and Astronautics, Emeritus
Norman Douglas Ham, ScD
Professor of Aeronautics and Astronautics, Emeritus
Walter Mark Hollister, ScD
Professor of Aeronautics and Astronautics, Emeritus
Jack Leo Kerrebrock, PhD
Professor of Aeronautics and Astronautics, Emeritus
Yao Tzu Li, ScD
Professor of Aeronautics and Astronautics, Emeritus
James Wah Mar, ScD
Professor of Aeronautics and Astronautics, Emeritus
Winston Roscoe Markey, ScD
Professor of Aeronautics and Astronautics, Emeritus
Earll Morton Murman, PhD
Ford Professor of Engineering, Emeritus
Professor of Aeronautics and Astronautics and Engineering Systems, Emeritus
Theodore Hsueh-Huang Pian, ScD
Professor of Aeronautics and Astronautics, Emeritus
Robert Channing Seamans, Jr., ScD
Professor of Aeronautics and Astronautics, Emeritus

Thomas Brown Sheridan, ScD, D (hon)
Professor of Aeronautics and Astronautics and Engineering and Applied Psychology, Emeritus
Robert Warren Simpson, PhD
Professor of Aeronautics and Astronautics, Emeritus
Leon Trilling, PhD
Professor of Aeronautics and Astronautics, Emeritus
Wallace Earl Vander Velde, ScD
Professor of Aeronautics and Astronautics, Emeritus
Emmett Atlee Witmer, ScD
Professor of Aeronautics and Astronautics, Emeritus

Professors emeriti
Eugene Edzards Covert, ScD
T. Wilson Professor of Aeronautics and Astronautics, Emeritus
John Dugundji, ScD
Professor of Aeronautics and Astronautics, Emeritus
Shaoul Ezekiel, ScD
Professor of Aeronautics and Astronautics and Electrical Engineering, Emeritus
Robert Louis Halfman, SM
Professor of Aeronautics and Astronautics, Emeritus
Norman Douglas Ham, ScD
Professor of Aeronautics and Astronautics, Emeritus
Walter Mark Hollister, ScD
Professor of Aeronautics and Astronautics, Emeritus
Jack Leo Kerrebrock, PhD
Professor of Aeronautics and Astronautics, Emeritus
Yao Tzu Li, ScD
Professor of Aeronautics and Astronautics, Emeritus
James Wah Mar, ScD
Professor of Aeronautics and Astronautics, Emeritus
Winston Roscoe Markey, ScD
Professor of Aeronautics and Astronautics, Emeritus
Earll Morton Murman, PhD
Ford Professor of Engineering, Emeritus
Professor of Aeronautics and Astronautics and Engineering Systems, Emeritus
Theodore Hsueh-Huang Pian, ScD
Professor of Aeronautics and Astronautics, Emeritus
Robert Channing Seamans, Jr., ScD
Professor of Aeronautics and Astronautics, Emeritus
The mission of the Department of Biological Engineering (BE) is to educate leaders and generate and communicate new knowledge fusing engineering with modern molecular-to-genomic 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 Department’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, pharmacology, toxicology, 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 department’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, physical, 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 beyond human health care.

UNDERGRADUATE STUDY

Bachelor of Science in Biological Engineering

The Department of Biological Engineering offers an undergraduate curriculum emphasizing quantitative, engineering-based 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, ecology, and public health. 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 quantitative analysis and 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 subject Introduction to Biological Engineering Design, offered during the spring term of freshman year, provides a framework for understanding the Biological Engineering SB program.

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. The sophomore spring-term curriculum 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 outside the BE (Course 20) major. 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**

- 5.12 Organic Chemistry I plus
- 5.07 Biological Chemistry I or
- 7.05 General Biochemistry

**Engineering Core**

- 18.03 Differential Equations or
- 3.016 Mathematical Methods for Materials Scientists and Engineers
plus a subject that applies differential equations to solve systems or macroscopic rate problems including, but not limited to one of the following:

- 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
- 20.320 Analysis of Biomolecular & Cellular Systems
- 20.330J Fields, Forces, and Flows in Biological Systems
- 20.340 Materials for Biomedical Applications
- 20.360J Cell and Tissue Engineering
- 20.361J Molecular and Engineering Aspects of Biotechnology
- 20.370J Quantitative Physiology: Cells and Tissues
- 20.37J Quantitative Physiology: Organ Transport Systems
- 20.390J Foundations of Computational and Systems Biology

### Restricted Electives

**One of the following:**

- 20.342J Molecular Structure of Biological Materials
- 20.380J Biotechnology and Engineering
- 20.411J Cell-Matrix Mechanics
- 20.441J Biomaterials—Tissue Interactions
- 20.451J Design of Medical Devices and Implants
- 20.481J Fundamental Limits of Biological Measurement
- 3.052J Nanomechanics of Materials and Biomaterials
- 6.121J Biomechanics Project Laboratory
- 6.555J Biomedical Signal and Image Processing

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

<table>
<thead>
<tr>
<th>Required 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</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 5.12 and 18.03 in the Course 20 Program]</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement [can be satisfied by 20.109]</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 Course 20 Program

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

<table>
<thead>
<tr>
<th>Required Core Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GiR)</td>
<td>162</td>
</tr>
<tr>
<td>20.101 Thermodynamics of Biomolecular Systems, 12; Calculus II (GiR), Chemistry (GiR)</td>
<td></td>
</tr>
<tr>
<td>5.12 Organic Chemistry, 12, REST, Chemistry (GiR)</td>
<td></td>
</tr>
<tr>
<td>20.109 Laboratory Fundamentals in Biological Engineering, 15, LAB, CI-M; Biology (GiR); Chemistry (GiR); permission of instructor</td>
<td></td>
</tr>
<tr>
<td>7.09 Genetics, 12; Biology (GiR)</td>
<td></td>
</tr>
<tr>
<td>6.00 Introduction to Computer Science and Programming, 12</td>
<td></td>
</tr>
<tr>
<td>5.07 Biological Chemistry I, 12; REST, 5.12 or 7.06 Cell Biology, 12; 7.03, 7.05</td>
<td></td>
</tr>
<tr>
<td>7.05 General Biochemistry, 12, REST; 5.12 and Biology (GiR); or permission of instructor</td>
<td></td>
</tr>
<tr>
<td>20.310J Molecular, Cellular, and Tissue Biomechanics, 12; 18.03 or 3.016; Biology (GiR); 2.370 or 20.110/2.772</td>
<td></td>
</tr>
<tr>
<td>20.320 Analysis of Biomolecular and Cellular Systems, 12; 20.110/2.772; 18.03; 6.00; 5.07 or 7.05</td>
<td></td>
</tr>
<tr>
<td>20.330J Fields, Forces, and Flows in Biological Systems, 12; 2.005, 6.021, 20.320, or permission of instructor</td>
<td></td>
</tr>
<tr>
<td>20.309J Biological Engineering II: Instrumentation and Measurement, 15; 18.03</td>
<td></td>
</tr>
</tbody>
</table>

### Departmental Program Units That Also Satisfy the GiRs

<table>
<thead>
<tr>
<th>Unrestricted Electives</th>
<th>(56)</th>
</tr>
</thead>
</table>

### 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.
Science/Engineering Elective

One additional subject from the list of Biomedical Engineering Core electives above and one subject from the following, or two additional subjects from the list of Biomedical Engineering Core electives above (no further elective is required):

- 20.104J Chemicals in the Environment: Toxicology and Public Health
- 20.109 Laboratory Fundamentals in Biological Engineering
- 20.201 Mechanisms of Drug Actions
- 20.450 Molecular and Cellular Pathophysiology
- 3.074 Organic and Biomaterials Chemistry
- 7.02 Introduction to Environmental Systems
- 7.03 Genetics
- 7.06 Cell Biology
- 7.20J Human Physiology
- 10.702 Introductory Experimental Biology and Communication

Laboratory Core

One of the following:
- 20.109 Laboratory Fundamentals in Biological Engineering
- 5.310 Laboratory Chemistry
- 7.02 Introduction to Experimental Biology and Communication
- 10.702 Introductory Experimental Biology and Communication

Restricted Electives

One of the following:
- 20.URG Undergraduate Research Opportunities
- 1.080 Environmental Chemistry and Biology
- 1.725J Chemicals in the Environment: Fate and Transport
- 1.89 Environmental Microbiology
- 5.07 Biological Chemistry I
- 7.05 General Biochemistry
- 7.06 Cell Biology
- 7.28 Molecular Biology
- 5.23 Atmospheric Chemistry
- 17.32 Environmental Politics and Policy

Minor Program in Toxicology and Environmental Health

The Department of Biological Engineering offers an undergraduate Minor in Toxicology and Environmental Health. The goal of this program is to meet the growing demand for undergraduates to acquire the intellectual tools needed to understand and assess the impact of new products and processes on human health, and to provide a perspective on the risks of human exposure to synthetic and natural chemicals, physical agents, and microorganisms.

Given the importance of environmental education at MIT, the program is designed to be accessible to any MIT undergraduate. The 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 Introduction to Biological Engineering.

Core Subjects

- 20.102 Macroparasitology and Population Genetics
- 20.104J Environmental Risks for Common Diseases
- 20.106 Systems Microbiology

Graduate Study

Doctoral Program in Biological Engineering

The Department of Biological Engineering 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 Department of Biological Engineering can carry out their research as part of a number of multi-investigator, multidisciplinary 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 Koch Institute for Integrative 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

Inquiries

For further information on the undergraduate programs, please visit the Biological Engineering website at http://web.mit.edu/be/ or contact the BE Academic Office, Room 56-651, 617-253-1712.

GRADUATE STUDY

Doctoral Program in Biological Engineering

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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) program is a five-year program leading to a bachelor’s degree in a science or engineering discipline along with a Master of Engineering in Biomedical Engineering. The program emphasizes the fusion of engineering with modern molecular-to-genomic biology, as in our SB and PhD degree programs. Admission to the MEBE program is open only to MIT undergraduate students, and requires candidates to demonstrate adequate quantitative and engineering credentials through their undergraduate coursework.

In addition to satisfying the requirements of their departmental program, candidates also are expected to complete subjects in differential equations (18.03); one engineering transport or systems subject (e.g., 2.005, 3.185, 6.002, 10.310); organic chemistry (5.12); biochemistry (7.05 or 5.07); and two of the core subjects from the Biomedical Engineering Minor.

Applications to the MEBE program are accepted from students in any of the departments in the School of Engineering or School of Science. Students interested in applying to the
MEBE 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, objectives, and program requirements can be obtained by contacting Professor Jongyoon Han, jyhan@mit.edu; Professor Darrell Irvine, djirvine@mit.edu; or the BE Academic Office, Room 56-651, 617-253-1712.

Program Requirements
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:
20.410J Molecular, Cellular, and Tissue Biomechanics
20.420J Biomolecular Kinetics and Cellular Dynamics
20.430J 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 that must be approved by the program director. The thesis is an original work of research, design, or development. If the supervisor is not a member of the Department of Biological Engineering, a reader who belongs to the BE faculty must also approve and sign the thesis. The student submits a thesis proposal by the end of the fourth year.

Inquiries
For further information on the graduate programs, please visit the Biological Engineering website at http://web.mit.edu/be/ or contact the BE Academic Office, Room 56-651, 617-253-1712.

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 from a participating engineering department. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description under Engineering Systems Division or visit http://lfm.mit.edu/.

FACULTY AND STAFF

Faculty and Teaching Staff
Douglas A. Lauffenburger, PhD
Whitaker Professor of Biological Engineering, Biology, and Chemical Engineering
Department Head

Professors
Angela M. Belcher, PhD
Germeshausen Professor of Materials Science and Biological Engineering
Arup Chakraborty, PhD
Haslam Professor of Chemical Engineering, Chemistry, and Biological Engineering
Peter C. Dedon, PhD, MD
Professor of Toxicology and Biological Engineering
Edward F. DeLong, PhD
Professor of Environmental and Biological Engineering
C. Forbes Dewey, Jr., PhD
Professor of Mechanical Engineering and Bioengineering
John Martin Essigmann, PhD
Professor of Chemistry, Toxicology, and Biological Engineering
James G. Fox, DVM
Professor of Toxicology
Director, Division of Comparative Medicine
Linda Griffith, PhD
S.E.T.I. Professor of Biological and Mechanical Engineering
Director, Biotechnology Process Engineering Center
Alan J. Grodzinsky, PhD
Professor of Electrical, Mechanical, and Biological Engineering
Director, Center for Biomedical Engineering
Roger D. Kamm, PhD
Germeshausen Professor of Biological and Mechanical Engineering
Alexander M. Klibanov, PhD
Novartis Professor of Chemistry and Biological Engineering
Robert S. Langer, ScD
Professor of Chemical and Biomedical Engineering
Institute Professor
Harvey F. Lodish, PhD
Professor of Biology and Biological Engineering
Member, Whitehead Institute for Biomedical Research
Paul T. Matsudaira, PhD
Professor of Biology and Biological Engineering
Member, Whitehead Institute for Biomedical Research
Leona D. Samson, PhD
American Cancer Society Professor
Professor of Toxicology and Biological Engineering
Director, Center for Environmental Health Sciences
Ram Sasishekaran, PhD
Underwood-Prescott Professor of Biological Engineering and Health Sciences and Technology
David B. Schauer, PhD, DVM
Professor of Biological Engineering and Comparative Medicine

Peter T. So, PhD
Professor of Mechanical and Biological Engineering

Subra Suresh, PhD
Ford Professor of Materials Science and Bioengineering

Steven R. Tannenbaum, PhD
Underwood-Prescott Professor of Toxicology and Chemistry

William G. Thilly, ScD
Professor of Toxicology

Bruce Tidor, PhD
Professor of Bioengineering and Computer Science

K. Dane Wittrup, PhD
Mares Professor of Chemical Engineering and Bioengineering

Ioannis V. Yannas, PhD
Professor of Polymer Science and Bioengineering

Associate Professors
Christopher B. Burge, PhD
Whitehead Associate Professor of Biology and Biological Engineering

Bevin P. Engelward, DSc
Associate Professor of Biological Engineering

Jongyoon Han, PhD
van Tassel Associate Professor of Electrical and Biological Engineering

Darrell J. Irvine, PhD
Bell Associate Professor of Biological Engineering and Materials Science

Alan P. Jasanoff, PhD
Associate Professor of Nuclear Science and Engineering, Biological Engineering, and Brain and Cognitive Sciences

Matthew J. Lang, PhD
Keck Associate Professor of Mechanical and Biological Engineering

Scott R. Manalis, PhD
Associate Professor of Biological and Mechanical Engineering, and Media Arts and Sciences

Forest White, PhD
Mitsui Associate Professor of Biological Engineering

Michael B. Yaffe, PhD
Associate Professor of Biology and Biological Engineering

Assistant Professors
Eric Alm, PhD
Assistant Professor of Biological and Environmental Engineering

Ernest Fraenkel, PhD
Assistant Professor of Biological Engineering

Kimberly Hamad-Schifferli, PhD
Burnell Assistant Professor of Mechanical and Biological Engineering

Jacquin C. Niles, PhD, MD
Assistant Professor of Biological Engineering

Visiting Professor
Peter K. Sorger, PhD
Visiting Professor of Biological Engineering

Lecturers
Noubar Afeyan, PhD
Laura C. Green, PhD
Sean Harriman, PhD
Natalie Kuldell, PhD
Agi Stachowiak, PhD
Steve Wasserman, SM

Research Staff
Senior Research Scientist
John S. Wishnok, PhD

Principal Research Scientist
Paul L. Skipper, PhD

Principal Research Engineer
Randall Rettberg, MS

Research Scientists
Robert G. Croy, PhD
Michael DeMott, PhD
Karel Domansky, PhD
Elena Gostiţeva, PhD

Ramesh Indrakanti, PhD
Vera Koledova, PhD
Rosa Liberan, PhD
Robert McCunney, PhD
Rahul Raman, PhD

Postdoctoral Associates
Neda Bagheri, PhD
Viral Brahmbhatt, PhD
Thomas Burg, PhD
Nisarnart Charoenlap, PhD
Liang Cui, PhD
Ajit Dash, PhD
James Delaney, PhD
Alfon Fichera, PhD
Mark Fleury, PhD
Ganpan Gao, PhD
Michel Godin, PhD
Luiš Godoy, PhD
William Grover, PhD
Arthur Goldsipe, PhD
Toomas Haller, PhD
Peyman Honarmandi, PhD
Eunsuk Kim, PhD
Min Young Kim, PhD
Orsolya Kiraly, PhD
Scott Knudsen, PhD
Kok Seong Lim, PhD
Anurag Maheshwari, PhD
Megan Mcbee, PhD
Partha Mondal, PhD
Alessandra Nita-Lazar, PhD
Shu-hua Nong, PhD
Gerard Ostheimer, PhD
Kartikeya Pant, PhD
Gregory Riddick, PhD
Rebecca Rugo, PhD
Jawon Seo, PhD
Peter Slade, PhD
Aravind Srinivasan, PhD
Hsiao-Lan Sun, PhD
Apinya Thiantanawat, PhD
Karthik Viswanthan, PhD
Lianrong Wang, PhD
Amanda Weaver, PhD
Courtney Williams, PhD
Michelle Williams, PhD
Leslie Woo, PhD
Esther Yeger-Lotem, PhD
Yu Zeng, PhD
Postdoctoral Fellows
Ido Bachelet, PhD
Diana Borenshtein, PhD
Seok Chung, PhD
Michael Godin, PhD
Pamela Kreeger, PhD
Werner Olipitz, PhD
Shelly Peyton, PhD
Manu Platt, PhD
Erin Prestwich, PhD
Laura Riva, PhD
Kari Schlicht, PhD
Ryo Sudo, PhD
Dominika Wiktor-Brown, PhD

Visiting Scientists
Per Ekstrom, PhD
Samuel Inman, PhD
Matthew Lim, PhD
S. Raguram, PhD
Elba Serrano, PhD
Lijiao Zhao, PhD

Professor Emeritus
Gerald N. Wogan, PhD
Professor of Chemistry and Biological Engineering, Emeritus
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 through a curriculum accredited by ABET. Course 10-C leads to the Bachelor of Science without this 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.

Bachelor of Science in Chemical Engineering/Course 10

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects 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 5.12; 5.07 or 7.05; 5.60; 10.301; and 18.03 or 18.034 in the Departmental Program]</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement [can be satisfied by 5.310]</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
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>5.12 Organic Chemistry I, 12, REST; Chemistry (GIR)</td>
<td>162</td>
</tr>
<tr>
<td>5.07 Biological Chemistry I, 12, REST; 5.12</td>
<td></td>
</tr>
<tr>
<td>7.05 General Biochemistry, 12, REST; 5.12, Biology (GIR); or permission of instructor</td>
<td></td>
</tr>
<tr>
<td>5.310 Laboratory Chemistry, 12, LAB; 5.12</td>
<td></td>
</tr>
<tr>
<td>5.60 Thermodynamics and Kinetics, 12, REST; Calculus II (GIR), Chemistry (GIR)</td>
<td></td>
</tr>
<tr>
<td>10.10 Introduction to Chemical Engineering, 12; Physics I (GIR), Calculus I (GIR), Chemistry (GIR)</td>
<td></td>
</tr>
<tr>
<td>10.213 Chemical and Biological Engineering Thermodynamics, 12; 5.60, 10.10</td>
<td></td>
</tr>
</tbody>
</table>

One of the following four subjects:

10.26 Chemical Engineering Projects Laboratory, 15, CI-M; 5.310, 7.02, or 10.702; 10.302
10.27 Chemical Engineering Processes Laboratory, 15, CI-M; 5.310, 10.32, 10.37
10.28 Chemical-Biological Engineering Laboratory, 15, CI-M; 5.310, 7.02, or 10.702; 7.05 or 5.07; or permission of instructor
10.29 Biological Engineering Projects Laboratory, 15, CI-M; 5.310, 7.02, or 10.702; 10.302

plus
10.301 Fluid Mechanics, 12, REST; 18.03, 10.10
10.302 Transport Processes, 12; 10.301
10.32 Separation Processes, 6; 10.213, 10.302
10.37 Chemical Kinetics and Reactor Design, 9; 5.60, 10.301
10.499 Integrated Chemical Engineering I, 8; 10.37
10.491 Integrated Chemical Engineering II, 8; 10.490

Two of the following three subjects:

10.492 Integrated Chemical Engineering Topics I, 4; 10.490
10.493 Integrated Chemical Engineering Topics II, 4; 10.490
10.494 Integrated Chemical Engineering Topics III, 4; 10.490

18.03 Differential Equations, 12, REST; Calculus II (GIR)
18.034 Differential Equations, 12, REST; Calculus II (GIR)

Restricted Electives

24
One subject in Chemical Engineering, except 10.UR, 10.URG, 10.THU, 10.792L, 10.810-10.816, 10.90-10.999
plus one laboratory subject from the following list:
3.014 Materials Laboratory, 12, LAB; CI-M
3.155/6.152 Micro/Nano Processing Technology, 12, CI-M; permission of the instructor
5.36 Biochemistry and Organic Laboratory, 12, CI-M
Module 4: Expression and Purification of Enzyme Mutants, 4; 5.07 or 7.05; Module 2 or 5.310; Module 5
Module 5: Kinetics of Enzyme Inhibition, 4; 5.07 or 7.05; Module 2 or 5.310; Module 4
Module 6: Organic Structure Determination, 4; 5.12; Module 2 or 5.310; 5.13
7.02 Introduction to Experimental Biology and Communication, 18, CI-M, LAB; Biology (GIR)
10.467 Polymer Science Laboratory, 15, CI-M; 5.12, 5.310
10.26 Chemical Engineering Projects Laboratory, 15, CI-M; 5.310, 7.02, or 10.702; 10.302
10.27 Chemical Engineering Processes Laboratory, 15, CI-M; 10.32, 10.37, 5.310
10.28 Chemical-Biological Engineering Lab, 15, CI-M; 5.310, 7.02, or 10.702; 7.05 or 5.07; or permission of instructor
10.29 Biological Engineering Projects Laboratory, 15, CI-M; 5.310, 7.02, or 10.702; 10.302
10.702 Introductory Experimental Biology and Communication, 18, CI-M, LAB; Biology (GIR)
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, 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, advanced subjects in chemistry or biology, 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 to a variety of specific areas, including energy and the environment, nanotechnology, polymers and colloids, surface science, catalysis and reaction engineering, systems and process design, and biotechnology. The degree requirements include the core chemical engineering subjects with a chemistry emphasis, and the opportunity to add subjects in any of these application areas.

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

This degree is intended for the student who is specifically interested 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.

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 degree in chemical engineering in two more years. Students are advised to discuss their proposed program with a Course 10 faculty advisor as soon as they become interested in a degree in chemical engineering. Faculty advisors are assigned to students as soon as they declare their major and then work with the students through graduation. Further information may be obtained from Dr. Barry S. Johnston.

Additional information is available on the Chemical Engineering Department website at [http://web.mit.edu/cheme/](http://web.mit.edu/cheme/). Undergraduates are encouraged to take part in the research activities of the department through the Undergraduate Research Opportunities Program (UROP).

**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 simultane-
ously gaining a broad exposure to the chemical engineering approach to solving problems.

Departmental requirements for Course 10-C are:

$5.60, 10.10, 10.213, 10.301, 10.302, \text{ and } 18.03$

-plus

one subject from the following:

$3.014, 3.155J/6.152J, 5.36, 7.02J/10.702J, 10.26, 10.28 \text{ or } 10.28L, 10.29 \text{ or } 10.467J$

-and

an additional subject from the above list or the following:

$1.018, 6.021J, 6.033, 6.111, 6.805, 14.05, 15.279 \text{ or } 15.301$

All of the above restricted elective subjects satisfy the Institute CI-M requirement. Students must also complete 180 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. Barry S. 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 engineering approach to solving problems.

Departmental Program units that also satisfy the GIRs

Restricted Electives in Science and Technology (REST) Requirement [can be satisfied from among $5.07, 5.12, 5.60, 7.03J, 7.05, 10.301, \text{ and } 18.03J$ or 18.034 in the Departmental Program]

Laboratory Requirement [can be satisfied by 7.02 or 10.702]

Total GIR Subjects Required for SB Degree

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>5.12 Organic Chemistry I, 12, REST; Chemistry (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>5.60 Thermodynamics and Kinetics, 12, REST; Calculus II (GIR), Chemistry (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>7.02 Introduction to Experimental Biology and Communication, 18, CI-M, LAB; Biology (GIR) or 10.702 Introduction to Experimental Biology and Communication, 18, CI-M, LAB; Biology (GIR)</td>
<td>18</td>
</tr>
<tr>
<td>7.03 Genetics, 12, REST; Biology (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>7.05 General Biochemistry, 12, REST; 5.12, Biology (GIR); or permission of instructor or 5.07 Biological Chemistry I, 12, REST; 5.12</td>
<td>12</td>
</tr>
<tr>
<td>7.06 Cell Biology, 12; 7.03J; 7.05*</td>
<td>12</td>
</tr>
<tr>
<td>10.10 Introduction to Chemical Engineering, 12; Physics I (GIR), Calculus I (GIR), Chemistry (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>10.213 Chemical and Biological Engineering Thermodynamics, 12; 5.60, 10.10</td>
<td>12</td>
</tr>
<tr>
<td>10.28 Chemical-Biological Engineering Laboratory, 15, CI-M; 5.310, 7.02, or 10.702; 10.702 or 5.07; or permission of instructor or 10.29 Biological Engineering Projects Laboratory, 15, CI-M; 5.310, 7.02, or 10.702; 10.302</td>
<td>15</td>
</tr>
<tr>
<td>10.301 Fluid Mechanics, 12, REST; 18.03, 10.10</td>
<td>12</td>
</tr>
<tr>
<td>10.302 Transport Processes, 12; 10.301*</td>
<td>12</td>
</tr>
<tr>
<td>plus 10.37 Chemical Kinetics and Reactor Design, 9; 5.60, 10.301</td>
<td>9</td>
</tr>
<tr>
<td>10.490 Integrated Chemical Engineering I, 8; 10.37</td>
<td>8</td>
</tr>
<tr>
<td>10.491 Integrated Chemical Engineering II, 8; 10.490</td>
<td>8</td>
</tr>
<tr>
<td>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*</td>
<td>12</td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GIR) or 18.034 Differential Equations, 12, REST; Calculus II (GIR)</td>
<td>12</td>
</tr>
</tbody>
</table>

Departmental Program units that also satisfy the GIRs

Unrestricted Electives

Total Units Beyond the GIRs Required for SB Degree

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.
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 the four core subject requirements in thermodynamics, reaction engineering, numerical methods, and transport phenomena, students select a research advisor and area for specialization, some of which are discussed below.

Thermodynamics and Molecular Computation. Thermodynamics is a cornerstone of chemical engineering. Processes as diverse as chemical production, bioreaction, creation of advanced materials, protein separation, and environmental treatment are governed by thermodynamics. The classical concepts of equilibrium, reversibility, energy, and entropy are basic to the analysis and design of these processes. The extension of classical thermodynamics to molecular scales by use of statistical mechanics has made molecular simulation an increasingly valuable tool for the chemical engineer. Prediction of macroscopic behavior from molecular computations is becoming ever more feasible. This venerable field continues to yield fruitful areas of inquiry.

Opportunities in the department for graduate study in this field include predicting properties of materials and polymers from molecular structure, applying quantum mechanics to catalyst design, supercritical fluid processing, the behavior of complex fluids with environmental and biomedical applications, phase equilibrium with simple and complex molecular species, immunology, protein stabilization, nucleation and crystallization of polymer and pharmaceuticals, and many other areas of classical and statistical thermodynamics.

Transport Processes. A fluid deforming and flowing as forces are imposed on it, its temperature varying as heat is transferred through it, the interdiffusion of its distinct molecular species—these are examples of the processes of transport. These transport processes govern the rates at which velocity, temperature, and composition vary in a fluid; chemical engineers study transport to be able to describe, predict, and manage these changes. Research includes experimental testing and analytical and computational modeling; its applications range among an enormous variety of mechanical, chemical, and biological processes.

Current work includes the study of polymer molecular theory and polymer processing, transport and separations in magnetorheological fluids, membrane separations, diffusion in complex fluids, defect formation and evolution in near-crystalline materials, microfluidics, fluid instability, transport in living tissue, numerical solution of field equations, and many other areas of transport phenomena.

Catalysis and Chemical Reaction Engineering. A simple chemical reaction—the rearrangement of electrons and bonding partners—occurs between two small molecules. From understanding the kinetics of the reaction, and the equilibrium extent to which it can proceed, come applications: the network of reactions during combustion, the chain reactions that form polymers, the multiple steps in the synthesis of a complex pharmaceutical molecule, the specialized reactions of proteins and metabolism. Chemical kinetics is the chemical engineer’s tool for understanding chemical change.

A catalyst influences the reaction rate. Catalysts are sought for increasing production, improving the reaction conditions, and emphasizing a desired product among several possibilities. The challenge is to design the catalyst, to increase its effectiveness and stability, and to create methods to manufacture it.

A chemical reactor should produce a desired product reliably, safely, and economically. In designing a reactor, the chemical engineer must consider how the chemical kinetics, often modified by catalysts, interacts with the transport phenomena in flowing materials. New microreactor designs are expanding the concept of what a reactor may do, how reactions may be conducted, and what is required to scale a process from laboratory to production.

Research is being conducted in the department at the forefront of catalyst design, complex chemical synthesis, bioreactor design, surface- and gas-phase chemistry, miniaturization of reactors, mathematical modeling of chemical reaction networks, and many other areas of chemical reaction engineering. Applications include the manufacturing of chemicals, refining of fuels for transportation and power, and microreactors for highly reactive or potentially hazardous materials.

Polymers. Wondrous materials found in nature and now synthesized in enormous quantity and variety, polymers find an ever-increasing use in manufactured products. Polymers are versatile because their properties are so wide-ranging, as is evident even in the conceptually simple polymers made from a single molecular species. The versatility becomes more profound in the copolymers made from multiple precursors, and the polymers compounded with filler materials. Research in polymers encompasses the chemical reactions of their formation, methods of processing them into products, means of modifying their physical properties, and the relationship between the properties and the underlying molecular- and solid-phase structure.

Graduate research opportunities in the department include studies of polymerization kinetics, non-Newtonian rheology, polymer thin films and interfaces, block copolymers, liquid crystalline polymers, nanocomposites and nanofibers, self-assembly and patterning, and many other areas of polymer science and engineering. In addition to a program in graduate study in polymers within the department, the interdisciplinary Program in Polymer Science and Technology (PPST) provides a community for researchers in the polymer field and offers a program of study that focuses on the interdisciplinary nature of polymer science and engineering.

Materials. The inorganic compounds found in nature are the basis for new materials made by modifying molecular composition (such as purifying silicon and doping it with selected impurities) and structure (such as control of pore and grain size). These materials have electronic, mechanical, and optical properties that support a variety of novel technologies. Other materials
are applied as coatings—thin films that create a functional surface. Still other materials have biological applications, such as diagnostic sensors that are compatible with living tissue, barriers that control the release of pharmaceutical molecules, and scaffolds for tissue repair. A new generation of biomaterials is being derived from biological molecules. Research in materials is wide-ranging and highly interdisciplinary, both fundamental and applied. In the department, materials research includes studies in plasma etching, thin-film chemical vapor deposition, crystal growth, nano-crystalline structure, molecular simulation, scaffolds for bone and soft tissue regeneration, biocompatible polymers, and many other areas of materials engineering.

**Surfaces and Nanostructures.** In many arrangements of matter, the interfaces between phases—more than their bulk compositions—are critical to the material structure and behavior. The surfaces of solids offer a platform for functional coating; coatings may be deposited from vapor, applied as a volatile liquid, or assembled from solution onto the solid, in a pattern determined by the molecular properties. This self-assembly tendency may be exploited to arrange desired patterns that have operational properties. Interfacial effects are also responsible for stable dispersions of immiscible phases, leading to fluids with complex microstructure. Other structured fluids arise from large molecules whose orientation in the solvent is constrained by molecular size and properties. In solids, tight control of pore size, grain size, chemical composition, and crystal structure offer a striking range of catalytic, mechanical, and electromagnetic properties. The understanding of gas-solid kinetics is crucial to the study of heterogeneous catalysis and integrated circuit fabrication. Structure is the basis for function, and by manipulating tiny length scales, the resulting nanostructure makes available new capabilities, and thus new technologies and products. Graduate study in surfaces and nanostructures may include studies of colloids, emulsions, surfactants, and other structured fluids with biological, medical, or environmental applications. It also encompasses thin films, liquid crystals, sol-gel processing, control of pharmaceutical morphology, nanostructured materials, carbon nanotubes, surface chemistry, surface patterning, and many other areas of nanotechnology and surface science.

**Biological Engineering.** Chemical engineering thermodynamics, transport, and chemical kinetics, so useful for manufacturing processes, are fruitful tools for exploring biological systems as well. Biological engineering research may be directed at molecular-level processes, the cell, tissues, the organism, and large-scale manufacturing in biotech processes. It may be applied to producing specialized proteins, genetic modification of cells, transport of nutrients and wastes in tissue, therapeutic methods of drug delivery, tissue repair and generation, purification of product molecules, and control strategies for complex bio-production plants. Its methods include analytical chemistry and biochemistry techniques, bioinformatic processing of data, and computational solution of chemical reaction and transport models. Biological engineering is an extraordinarily rich area for chemical engineers, and its consequences—theoretical, medical, commercial—will be far-reaching.

Opportunities in the department for graduate study in biological engineering include manipulation and purification of proteins and other biomolecules, research into metabolic processes, tissue regeneration, gene regulation, bioprocesses, bioinformatics, drug delivery, and biomaterials, to name a few. Both experimental and computational methods are used, including statistical mechanics and systems theory. 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. The Novartis-MIT Center for Continuous Manufacturing, another center of research activity involving chemical engineers, promises to revolutionize the chemical processing of pharmaceuticals.

**Energy and Environmental Engineering.** Making energy available to society requires finding and producing a range of fuels, improving the efficiency of energy use under the ultimate limits imposed by thermodynamics, and reducing the effects of these processes on the environment. The widespread use of fossil fuels increases the amount of carbon dioxide in the atmosphere, leading to concerns about global warming. Other sustainability indicators also suggest that we now need to transform our energy system to a more efficient, lower-carbon future. This transformation provides many opportunities for chemical engineers to evaluate and explore other energy supply options such as renewable energy from solar, biomass, and geothermal resources, nonconventional fuels from heavy oils, tar sands, natural gas hydrates, and oil shales. Developing technologies for transporting and storing thermal and electrical energy over a range of scales are also of interest.

Further environmental distress can result from manufacturing processes and society’s use of the manufactured products. The traditional response of treating process wastes is still useful, but there is growing emphasis on designing new processes to produce less waste. This might be done by improving catalysts to decrease unwanted by-products, finding alternatives to volatile solvents, and developing more effective separation processes. Chemical engineers are at work in all these areas, as well as developing alternative energy sources and assessing the effects of pollutants on human health.

In the department, students will find expertise in combustion, chemical reaction networks, renewable energy and upgrading of nonconventional fuels, carbon dioxide capture and sequestration, water purification and catalytic treatment of pollutants, global air pollution modeling, design of novel energy conversion processes, energy supply chains, and many other areas of energy and environmental engineering. Faculty in the department are actively involved in the MIT Energy Initiative.

**Systems Design and Simulation.** From early in the development of chemical engineering, processes were represented as combinations of unit operations. This concept was useful in analyzing processes, as well as providing a library of building blocks for creating new processes. Process and product design are imaginative activities, an artful blend of intuition and analysis. Design is aided by mathematical tools that simulate the behavior of the process or product and seek optimum performance. Effective use of simulation and optimization tools allows unexpected pathways to be explored, dangerous operating regions to be identified, and transient and accident conditions to be tested. Process and product systems engineering brings it all together, placing the technical features of a process or product in the context of operations,
Chemical Engineering

Student and Faculty

areas: thermodynamics, heat and mass transfer, and many other areas of systems engineering are being developed in the Department of Chemical Engineering. Such research leads to new prototypes for process systems, design of new molecules with desired properties, and processes with better operability, control, safety, and environmental performance.

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 I. 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 semester 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 under Engineering Systems Division or visit http://tppserver.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 6½-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 from a participating engineering department. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description under Engineering Systems Division or visit http://lfm.mit.edu/.

Doctor of Science or Doctor of Philosophy

Doctoral candidates are required to pass a written general examination early in their program of study. Given in January and May, the written examination is usually taken at the end of the first term in residence as a graduate student. There is also an oral general examination, which consists of the presentation of a thesis proposal to a faculty committee; this is normally done during the second year of residence. Completing a master's degree is not a prerequisite for entering the doctoral program or obtaining a doctoral degree.

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.

http://lfm.mit.edu/
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 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.

This program is described under 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, 617-253-4579, chemegrad@mit.edu.

Faculty and Staff

Faculty and Teaching Staff

Klavs Flemming Jensen, PhD
Warren K. Lewis Professor of Chemical Engineering
Department Head

Paula Therese Hammond, PhD
Bayer Professor of Chemical Engineering
Executive Officer

Professors

Robert Calvin Armstrong, PhD
Chevron Professor of Chemical Engineering
Professor of Chemical Engineering
Associate Director, MIT Energy Initiative

Paul Inigo Barton, PhD
Lammot du Pont Professor of Chemical Engineering

Daniel Blankschtein, PhD
Professor of Chemical Engineering

Arup K. Chakraborty, PhD
Robert T. Haslam Professor of Chemical Engineering
Professor of Chemistry and Biological Engineering
Graduate Admissions Officer

Robert Edward Cohen, PhD
Raymond A. and Helen E. St. Laurent Professor of Chemical Engineering

Clark Kenneth Colton, PhD
Professor of Chemical Engineering

Charles Leland Cooney, PhD
Robert T. Haslam Professor of Chemical and Biochemical Engineering
Faculty Director, Deshpande Center for Technological Innovation
Codirector, Program on the Pharmaceutical Industry

William Murray Deen, PhD
Carbon P. Dubbs Professor of Chemical Engineering
Graduate Officer

Karen Klincewicz Gleason, PhD
Alexander and I. Michael Kasser Professor of Chemical Engineering
Associate Dean for Research, School of Engineering

William H. Green, PhD
Professor of Chemical Engineering

Trevor Alan Hatton, PhD
Ralph Landau Professor of Chemical Engineering Practice
Director, David H. Koch School of Chemical Engineering Practice

Robert Samuel Langer, ScD
Kenneth J. Germeshausen Professor of Chemical and Biomedical Engineering
Institute Professor

Douglas Alan Lauffenburger, PhD
Whitaker Professor of Biological Engineering, Chemical Engineering, and Biology
Head, Biological Engineering Department

Gregory John McRae, PhD
Hoyt C. Hottel Professor of Chemical Engineering

Gregory Charles Rutledge, PhD
Lammot du Pont Professor of Chemical Engineering

Herbert Harold Sawin, PhD
Professor of Chemical and Electrical Engineering

Kenneth Alan Smith, ScD
Edwin R. Gilliland Professor of Chemical Engineering

George Stephanopoulos, PhD
Arthur Dehon Little Professor of Chemical Engineering

Gregory Stephanopoulos, PhD
Herbert H. Dow Professor of Chemical Engineering

Jefferson William Tester, PhD
Herbert H. Dow Professor of Chemical Engineering

Bernhardt Levy Trout, PhD
Professor of Chemical Engineering
Director, Novartis-MIT Center for Continuous Manufacturing
Cochair, Singapore-MIT Alliance, Chemical and Pharmaceutical Engineering
Daniel I. C. Wang, PhD  
Professor of Chemical Engineering  
Institute Professor  
Karl Dane Wittrup, PhD  
Carbon T. Dubbs Professor of Chemical Engineering and Bioengineering  

Associate Professors  
Patrick S. Doyle, PhD  
Associate Professor of Chemical Engineering  
Michael S. Strano, PhD  
Charles and Hilda Roddey Associate Professor of Chemical Engineering  
Preetinder Singh Virk, ScD  
Associate Professor of Chemical Engineering  

Assistant Professors  
J. Chris Love, PhD  
Texaco-Mangelsdorf Assistant Professor of Chemical Engineering  
Narendra Maheshri, PhD  
Raymond A. and Helen St. Laurent Assistant Professor of Chemical Engineering  
Kristala J. Prather, PhD  
Joseph R. Mares Assistant Professor of Chemical Engineering  

Adjunct Professors  
Robert Arthur Brown, PhD  
Warren K. Lewis Adjunct Professor of Chemical Engineering  
Alice Petry Gast, PhD  
Adjunct Professor of Chemical Engineering  
Jackie Yi-Ru Ying, PhD  
Adjunct Professor of Chemical Engineering  

Senior Lecturers  
Robert Fisher, PhD  
Barry S. Johnston, PhD  
Industrial Development Officer  
Undergraduate Officer  
Claude Lupis, PhD  

Lecturers  
Bonnie D. Burrell, BA  
William H. Dalzell, PhD  

Research Staff  

Research Engineers  
Jean-François P. Hamel  

Research Scientists  
Lev E. Bromberg  
Joanne K. Kelleher  

Technical Assistants  
Adrian A. Fay  
Kevin R. Yi  

Postdoctoral Associates  
Andrea Adamo  
Hal S. Alper  
Avni A. Argun  
Pradipto K. Bhattacharyya  
Georgios Bollas  
Andrea Centrone  
Shujun Chen  
Hao Cheng  
Naresh Chennamsetty  
Jong Hyun Choi  
Jayajit Das  
Seungpyo Hong  
Chih-Chen Hsieh  
Abhishek K. Jha  
Sandeep S. Karajanagi  
Veysel Kayser  
Byeong-Su Kim  
Vikram K. Kuppa  
Hyung-Il Lee  
Jung Ah Lee  
Effendi Leonard  
Abigail K. Jha  
Kerry P. Mahon  
Samuel C. G. Marre  
Ying Mei  
Teppei Ogura  
Victor A. Ovchinnikov  
Ajkumar Parayil Kumaran  
Luis Perez-Breva  
Alok Prasad  
Effendi Rusli  
Erik E. Santiso  
Seyed-Abdolreza Seyed-Reihani  
Changsil Song  
Dahai Tang  
Anish Tuteja  
Sreeyam Vaddiraju  
Vladimir Hristov Voynov  

Postdoctoral Fellows  
Joon Hyun Baik  
Seung Woo Cho  
Moon-Ho Ham  
Todd R. Hoare  
Sarah Hudson  
Dae Kun Hwang  
Ana Jaklenec  
Jong Ho Kim  
Woo-Jae Kim  
David R. Nielsen  
Cecilia Prego Rodríguez  
Sang Hwal Yoon  
Jamey D. Young  

Research Affiliates  
Steven A. Africk  
Efstrathios Avgoustiniatos  
Anuj Bellare  
Itzhak Isaac Berzin  
Dhananjay Dendukuri  
Yuliya Domnina  
Sergey Fridrikh  
Steven W. Griffiths  
Jeffrey S. Hrkach  
Orhan I. Karšišili  
Edward D. Kingsley  
Arthur L. Lafleur  
Michael M. Lipp  
Michael Modell  
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Orhun K. Muratoglu  
Samuel Ngai  
James J. Noble  
Mahnaz Nouri  
Klearhos K. Papas  
Hyoungshin Park  
Blaine A. Pfeifer  
Jason M. Ploeger  
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Sumil K. Sharma  
Norman F. Sheppard, Jr.  
Barry A. Solomon  
Brian Curtis Stephenson  
Brian R. Stoll
Mallikarjun Sundaram
Kathleen C. Swallow
Henri C. Tannas
Charles Alfred Vacanti
Joseph P. Vacanti

**Visiting Scientists**
Takuya Harada
Shaoyi Jiang
Yong Hoon Kim
Joseph Kost
Akihiko Kusanagi
Russell P. Lachance
Kenji Takahashi

**Professors Emeriti**
Raymond Frederick Baddour, ScD
Professor of Chemical Engineering, Emeritus
János Miklós Beér, ScD
Professor of Chemical and Fuel Engineering, Emeritus
Howard Brenner, EngScD
Willard Henry Dow Professor of Chemical Engineering, Emeritus
Jack Benny Howard, PhD
Professor of Chemical Engineering, Emeritus
Marcus Karel, PhD
Professor of Chemical and Food Engineering, Emeritus
Edward Wilson Merrill, ScD
Professor of Chemical Engineering, Emeritus
Adel Fares Sarofim, ScD
Professor of Chemical Engineering, Emeritus
Charles Nelson Satterfield, PhD
Professor of Chemical Engineering, Emeritus
James Wei, ScD
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 the design of functional and environmentally compatible facilities and infrastructure. Within this broad context, the Department of Civil and Environmental Engineering is especially concerned with:

- 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 sociopolitical 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 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; environmental biology; geotechnical and geo-environmental engineering; environmental fluid dynamics; coastal engineering; hydrology and water resources; materials and structures; transportation systems and other engineering systems (including information technology and infrastructure).

**Undergraduate Study**

The Department of Civil and Environmental Engineering offers three undergraduate programs: 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 in Environmental Engineering.

Each of these programs 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

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 and provides a direct transition to the department’s Master of Engineering program. The 1-E program is ABET accredited and is sufficiently flexible to prepare students for careers in medicine or environmental law.

Bachelor of Science in Civil Engineering/Course 1-E

General Institute Requirements (GIRs)  
Science Requirement  
- 6 subjects

Restricted Electives in Science and Technology (REST) Requirement  
- [can be satisfied by 1.00 or 1.018] and [18.03 in the Departmental Program]  
- 2 subjects

Laboratory Requirement  
[can be satisfied by 1.101 and 1.102 in the Departmental Program]  
- 1 subject

Total GIR Subjects Required for SB Degree  
17 subjects

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  
- 159 units

Departmental Program Units That Also Satisfy the GIRs  
Unrestricted Electives  
- 48 units

Total Units Beyond the GIRs Required for SB Degree  
183 units

Notes  
* Alternate prerequisites and corequisites 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 Environmental Engineering Science/Course 1-E

**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 [one subject can be satisfied by 1.800, 11.002, 11.033, or 16.02 in the Departmental Program]</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 1.008 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>
</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**

- **Units**: 168
- **Core**
  - **1.018J** Ecology I: The Earth System, 12, REST, CI-M
  - **1.020** Ecology II: Engineering for Sustainability, 12
  - **1.030** Engineering Mechanics I, 12; Physics I (GIR), Calculus II (GIR)
  - **1.060** Engineering Mechanics II, 12; 18.03*  
  - **1.080** Differential Equations, 12, REST; Calculus II (GIR)
  - **1.015** Senior Civil and Environmental Engineering Design, 12, CI-M; permission of instructor

One of the following two subjects:

- **1.000** Introduction to Computers and Engineering Problem Solving, 12, REST; Calculus I (GIR)
  - **1.010** Uncertainty in Engineering, 12; Calculus II (GIR)

**Environmental Engineering Science**

- **1.065** Transport Processes in the Environment, 12; 1.060
- **1.070** Introduction to Hydrology, 12; 1.060, 1.061, 1.062
- **1.080** Environmental Chemistry and Biology, 12; 1.107, Chemistry (GIR), Biology (GIR)
- **1.083** Environmental Health Engineering, 12; 1.061
- **1.106** Environmental Fluid Transport Processes and Hydrology Laboratory, 6, 1/2 LAB; 1.061, 1.070  
- **1.107** Environmental Chemistry and Biology Laboratory, 6, 1/2 LAB; 1.080

**Economics and Public Policy**

One of the following four subjects:

- **1.000** Environmental Law, Policy, and Economics: Pollution Prevention & Control, 12; HASS
  - **11.002** Making Public Policy, 12; HASS-D, CI-H
  - **11.122** Society and Environment, 12; HASS
  - **14.04** Principles of Microeconomics, 12; HASS

**Laboratory**

- **1.101** Introduction to Civil and Environmental Engineering Design I, 6, 1/2 LAB; 1.108, 1.050
- **1.102** Introduction to Civil and Environmental Engineering Design II, 6, 1/2 LAB; 1.060, permission of instructor

**Restricted Elective**

One advanced subject from the following list:

- **1.070** Global Change Science, 12; 18.03, 5.60
- **1.64** Physical Limnology, 12; 1.060, 1.061
- **1.69** Introduction to Coastal Engineering, 12; 1.061
- **1.72** Groundwater Hydrology, 12; 1.061
- **1.73** Water Resource Systems, 12; 1.070*
- **1.77** Water Quality Control, 12; 1.060
- **1.83** Environmental Organic Chemistry, 12; 5.60, 18.03
- **1.89** Environmental Microbiology, 12; 7.014

**Departmental Program Units That Also Satisfy the GIRs**

- **Units**: 48

**Unrestricted Electives**

- **Units**: 48

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

- **Units**: 180

No subject can be counted both as part of the 12-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 and corequisites are listed in the subject description.
- **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

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.
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 MIT 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 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 Susann Luperfoy, executive director, Undergraduate Practice Opportunities Program, Room 12-193, 617-253-0055, fax 617-253-8457, luperfoy@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.

Bachelor of Science as recommended by the Department of Civil and Environmental Engineering/Course 1-A

<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 (REST) Requirement [can be satisfied by 1.018 and 18.03 in the Departmental Program]</td>
<td>8</td>
</tr>
<tr>
<td>Laboratory Requirement [can be satisfied by 1.101 and 1.102 in the Departmental Program]</td>
<td>2</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
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics).

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>84</td>
</tr>
<tr>
<td>1.018J Ecology I: The Earth System, 12, REST, CI-M</td>
<td>12</td>
</tr>
<tr>
<td>1.020 Ecology II: Engineering for Sustainability, 12</td>
<td>12</td>
</tr>
<tr>
<td>1.050 Engineering Mechanics I, 12; Physics I (GIR), Calculus II (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>1.060 Engineering Mechanics II, 12; 18.03*</td>
<td>12</td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST, Calculus II (GIR)</td>
<td>12</td>
</tr>
</tbody>
</table>

One of the following two subjects:
1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; Calculus I (GIR) | 12       |
1.010 Uncertainty in Engineering, 12; Calculus II (GIR) | 12       |

Laboratory
1.101 Introduction to Civil and Environmental Engineering Design I, 6, 1/2 LAB; 1.018, 1.050 | 6        |
1.102 Introduction to Civil and Environmental Engineering Design II, 6, 1/2 LAB; 1.060, permission of instructor | 6        |

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

<table>
<thead>
<tr>
<th>Unrestricted Electives</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td></td>
</tr>
</tbody>
</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 and corequisites are listed in the subject description.

To satisfy the CI-M component of the Communication Requirement, students must take the department’s two CI-M subjects (1.023 and 1.038) 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.
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
or
1.036   Structural and Geotechnical Engineering Design

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

1.018J  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 Laboratory
and one of the following four subjects:
1.801J  Environmental Law, Policy, and Economics: Pollution Prevention and Control
11.002J Fundamentals of Public Policy
11.122J Society and Environment
14.01   Principles of Microeconomics

Substitution of equivalent subjects offered by other departments is allowed, with permission of the minor advisor. However, at least three full subjects (12 units) 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 Transportation, Master of Science, 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. Beginning in fall 2008 there will be four specialty areas: high performance structures, geotechnical engineering, environmental engineering, and a new specialty area in transportation. The program 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; this experience is composed of a required group project and an individual, practice-oriented thesis.

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 (including environmental chemistry and environmental biology), 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, and earthquake engineering.

Structures and materials gives students a fundamental understanding of the behavior of structures and the materials from which they are made. In the academic program, emphasis is placed on structural mechanics, behavior and design of concrete structures, structural dynamics and seismic design, advanced concepts of structural control, motion-based design,
durability of materials and structures, and the innovative use of materials in effective structural systems. The program also emphasizes the mechanical behavior of construction materials and mechanics of materials at scales ranging from nano to macro relating the continuum scale to the atomistic scale.

The current research program includes projects on the durability of concrete-epoxy FRP (fiber-reinforced plastics) multimaterial composite systems and interface fracture at micro and meso levels; structural assessment using electromagnetic waves and development of image reconstruction algorithms; advanced repair technologies for concrete structures using composite materials; characterization of the mechanical properties of concrete under moisture, temperature, and cyclic environmental conditions; atomistic modeling and molecular dynamics by applying computational mechanics to chemically complex materials, including most civil engineering materials; chemo-physical analysis of cementitious and natural materials from their heterogeneous constituents to the homogenous scale; and durability mechanics.

Environmental fluid mechanics and coastal engineering emphasizes physical processes of water flow essential to the understanding, protection, and improvement of the environment. The program includes theoretical, numerical, field and laboratory studies, and the development of practical models and strategies for practice. Interaction of physical processes with chemical and biological processes is also stressed. Major research themes include microbiological fluid dynamics, wave dynamics, wave-current interaction, sediment transport, carbon dioxide sequestration, lake and wetland hydrodynamics, coastal circulation, and water quality modeling. Related subjects in oceanography, ocean engineering, and microfluidics are offered by other MIT departments and at the Woods Hole Oceanographic Institution.

Offerings in hydrology emphasize the close relationship between meteorology, climate, surface water, soil, and groundwater. Issues of water quantity and quality, as well as resource management, are studied. Subjects cover deterministic and stochastic aspects of surface and groundwater, hydrometeorology, hydroclimatology, limnology, and water resource systems. Subjects are complemented by other MIT offerings in the earth and ocean sciences. Research activities encompass theoretical work as well as laboratory and field experimental studies. Some topics of interest are the characterization of groundwater contamination, climate change, integration of remote sensing data and geographical information systems into hydrologic modeling, hydrologic parameterization of global climate models, field and theoretical quantification of runoff mechanisms, and an understanding of the development of river basins.

The programs in environmental chemistry, environmental biology, and environmental engineering range from fundamental science to engineering applications. Students may choose to pursue either an in-depth study in one of these areas or an interdisciplinary program drawing upon the full range of offerings. Subjects offered cover the basics of aquatic chemistry and microbiology, ecology, biogeochemistry, and toxicology. Research opportunities encompass laboratory, field, and modeling studies, chemical and microbial transformations, microbial oceanography, molecular ecology and genomics, 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 doctoral 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. More information about individual graduate programs can be obtained at http://cee.mit.edu/ or by writing to cee-admissions@mit.edu.

Financial Assistance
The research of the department is an integral part of the graduate program, and approximately 120 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 Office of the Dean for Graduate Education 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 two required core subjects and at least three additional transportation or related subjects, in addition to the master’s thesis. Generally, the three additional subjects relate to an area of specialization, although this is not required. Common areas of specialization include urban transportation, air transportation, planning methods, logistics, and policy.

For more information, see the MST program description on the department’s website at 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 with a required 6.5-month internship 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 under Engineering Systems Division in Part 2 or visit 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 under Interdisciplinary Graduate Programs in Part 2.

Inquiries
Detailed information about the academic policies and programs of the department may be obtained by writing to or visiting the Academic Programs Office, Room 1-281, 617-253-9723, fax 617-258-6775, cee-apo@mit.edu, http://cee.mit.edu/.

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. In addition to the Parsons and Pierce Laboratories, the department collaborates interdepartmentally with other laboratories described below.

Ralph M. Parsons Laboratory
Located on the east campus, the Ralph M. Parsons Laboratory for Environmental Science and Engineering 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 60 graduate students and 18 faculty members have offices on the premises.

Facilities exist for hydrodynamic studies involving flow through vegetation, 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, molecular biology, genomics, microbial ecology, and biochemistry. Especially notable instrumentation includes several GCs, a GC-MS, LC-MS, and several HPLCs, two flame AAs, 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 several -80°C freezers. One laboratory, recently renovated, is a dedicated teaching facility for environmental engineering and aquatic chemistry and biology. Equipment is available for instruction in a wide range of field sampling methods, biological and microbiological evaluations, and instrumental chemical analyses of natural waters. A new, state-of-the-art inductively coupled plasma spectrometer was recently acquired. Computer facilities include a 100-processor Beowulf (parallel computing) cluster, among other computer clusters.

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 90 graduate students and 20 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 five major areas: infrastructure, geotechnology, geoenvironment, information and management, and transportation. Among the classrooms is the state-of-the-art Bechtel Lecture Hall. The facilities include an undergraduate teaching/project laboratory and a materials testing laboratory that 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 automated universal test frames, a biaxial loading system, an environmental chamber, and an environmentally controlled nano-indentation system. The geotechnical laboratories combine a broad range of equipment from conventional to state-of-the-art to specialty research devices. Capabilities and equipment include industrial radiography; centralized data acquisition; computer-automated consolidation, triaxial and high-pressure triaxial cells; simple shear devices; a hollow cylinder apparatus and a medium-sized centrifuge.
The Pierce Laboratory offers diverse and advanced computational facilities, including a large Linux cluster, a large Athena cluster, and networked Sun, Digital, and Windows workstations. The computing facilities feature various software development packages, visualization workstations, and an extensive set of structural, project management, geotechnical and materials analysis programs such as SAP, STRUDL, PLAXIS, MATLAB, AUTOCAD, FORTRAN, Primavera, Crystal Ball, ADINA, and ABAQUS, as well as molecular dynamics applications for the analysis of nanomechanics of natural and biological structures.

**Laboratory for Energy and the Environment**
The Education Program of the Laboratory for Energy and the Environment (LFEES) 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 LFEES 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 System Initiative**
The Earth System 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 the ESI website at [http://esi.mit.edu/](http://esi.mit.edu/).

**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 available under Interdisciplinary Research and Study in Part 1 or at the CGCS website, [http://mit.edu/cgcs/](http://mit.edu/cgcs/).

**Faculty and Staff**

**Faculty and Teaching Staff**
- Patrick Jaillet, PhD
- Edmund K. Turner Professor of Civil and Environmental Engineering
- Department Head
- Ole Secher Madsen, ScD
- Donald and Martha Harleman Professor
- Professor of Civil and Environmental Engineering
- Associate Department Head for Education

**Professors**
- Cynthia Barnhart, PhD
- Professor of Civil and Environmental Engineering and Engineering Systems
- Associate Dean for Academic Affairs, School of Engineering
- Moshe Emanuel Ben-Akiva, PhD
- Professor of Civil and Environmental Engineering
- Rafael Luis Bras, ScD
- Professor of Civil and Environmental Engineering
  (On leave)
- Oral Buyukozturk, PhD
- Professor of Civil and Environmental Engineering

Sallie W. Chisholm, PhD
Lee and Geraldine Martin Professor of Environmental Studies
Professor of Civil and Environmental Engineering and Biology
Jerome Joseph Connor, Jr., ScD
Professor of Civil and Environmental Engineering
Edward F. DeLong, PhD
Professor of Civil and Environmental Engineering and Biological Engineering
Richard Lawrence de Neufville, PhD
Professor of Civil and Environmental Engineering
Dara Entekhabi, PhD
Bacardi and Stockholm Water Foundation Professor
Professor of Civil and Environmental Engineering
Lorna Jane Gibson, PhD
Matoula S. Salapatas Professor of Materials Science and Engineering
Professor of Civil and Environmental Engineering and Mechanical Engineering
Philip Michael T. Gschwend, PhD
Ford Professor of Engineering
Professor of Civil and Environmental Engineering
Harold Field Hemond, PhD
William E. Leonhard Professor of Engineering
Professor of Civil and Environmental Engineering
Eduardo Kausel, PhD
Professor of Civil and Environmental Engineering
Richard C. Larson, PhD
Mitsui Professor
Professor of Civil and Environmental Engineering and Engineering Systems
Steven Richard Lerman, PhD
Class of 1922 Professor
Professor of Civil and Environmental Engineering
Vice Chancellor and Dean for Graduate Education

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David Hunter Marks, PhD
Morton and Claire Goulder Family Professor
Professor of Civil and Environmental Engineering and Engineering Systems

Dennis B. McLaughlin, PhD
H. M. King Bhumipol Professor
Professor of Civil and Environmental Engineering

Chiang Chung Mei, PhD
Ford Professor of Engineering
Professor of Civil and Environmental Engineering

Fred Moavenzadeh, PhD
James Mason Crafts Professor
Professor of Civil and Environmental Engineering and Engineering Systems

Heidi M. Nepf, PhD
Professor of Civil and Environmental Engineering
MacVicar Faculty Fellow

Amedeo Rodolfo Odoni, PhD
Professor of Aeronautics and Astronautics and Civil and Environmental Engineering

Daniel Roos, PhD
Professor of Engineering Systems and Civil and Environmental Engineering

Yossi Sheffi, PhD
Professor of Civil and Environmental Engineering and Engineering Systems

David Simchi-Levi, PhD
Professor of Civil and Environmental Engineering and Engineering Systems

Joseph Martin Sussman, PhD
JR East Professor
Professor of Civil and Environmental Engineering and Engineering Systems

Franz-Josef Ulm, PhD
Professor of Civil and Environmental Engineering

Daniele Veneziano, PhD
Professor of Civil and Environmental Engineering

Andrew J. Whittle, PhD
Professor of Civil and Environmental Engineering

Nigel Henry Moir Wilson, PhD
Professor of Civil and Environmental Engineering

Martin F. Polz, PhD
Associate Professor of Civil and Environmental Engineering

John Williams, PhD
Associate Professor of Civil and Environmental Engineering and Engineering Systems

Assistant Professors

Eric J. Alm, PhD
Assistant Professor of Civil and Environmental Engineering and Biological Engineering

Markus J. Buehler, PhD
Esther and Harold E. Edgerton Career Development Professor
Assistant Professor of Civil and Environmental Engineering

Ruben Juanes, PhD
Assistant Professor of Civil and Environmental Engineering

Roman Stocker, PhD
Doherty Professor in Ocean Utilization
Assistant Professor of Civil and Environmental Engineering

Janelle Thompson, PhD
Assistant Professor of Civil and Environmental Engineering

Senior Lecturers

E. Eric Adams, PhD
John T. Germaine, PhD
George Kocur, PhD
Susan Murcott, MS
Frederick P. Salvucci, MS
Peter Shanahan, PhD

Lecturers

Charles C. Caldart, JD
Sheila Frankel, MA
Lisa Grebner, MS
V. Judson Harvard, PhD
Lucy Jen, PhD
Paul Kassabian, MS
Mikel Murga, MS
Derish Wolf, MBA
Windsor Sung, PhD

Research Staff

Senior Research Engineer

E. Eric Adams, PhD

Senior Research Associate

John T. Germaine, PhD

Principal Research Engineer

Earle Williams, PhD

Research Engineer

John Eppley, PhD
John MacFarlane, SM

Research Associate

Sheila L. Frankel, MA

Research Scientists

Katherine Huang, SM
Asunción Martínez, PhD
Marcia Osbourne, PhD

Professors Emeriti

Peter Sturges Eagleson, ScD
Edmund K. Turner Professor of Civil and Environmental Engineering, Emeritus

Lynn Walter Gelhar, PhD
Professor of Civil and Environmental Engineering, Emeritus

Robert Joseph Hansen, ScD
Professor of Civil and Environmental Engineering, Emeritus

Charles Cushing Ladd, ScD
Edmund K. Turner Professor of Civil and Environmental Engineering, Emeritus

Thomas William Lambe, ScD
Edmund K. Turner Professor of Civil and Environmental Engineering, Emeritus

Robert Daniel Logcher, ScD
Professor of Civil and Environmental Engineering, Emeritus

Frank Edward Perkins, ScD
Professor of Civil and Environmental Engineering, Emeritus

Robert Van Duyne Whitman, ScD
Professor of Civil and Environmental Engineering, Emeritus
Electrical engineers and computer scientists are everywhere—in industry and research areas as diverse as computer and communication networks, electronic circuits and systems, lasers and photonics, semiconductor and solid-state devices, nanoelectronics, biomedical engineering, computational biology, artificial intelligence, robotics, design and manufacturing, control and optimization, computer algorithms, games and graphics, software engineering, computer architecture, cryptography and computer security, power and energy systems, financial analysis, and many more. The infrastructure and fabric of the information age, including technologies such as the internet and the web, search engines, cell phones, high-definition television, and magnetic resonance imaging, are largely the result of innovations in electrical engineering and computer science. The Department of Electrical Engineering and Computer Science at MIT and its graduates have been at the forefront of a great many of these advances. Current work in the department holds promise of continuing this record of innovation and leadership, in both research and education, across the full spectrum of departmental activity.

The career paths and opportunities for EECS graduates cover a wide range and continue to grow: fundamental technologies, devices, and systems based on electrical engineering and computer science are pervasive and essential to improving the lives of people around the world and managing the environments they live in. The basis for the success of EECS graduates is a deep education in engineering principles, built on mathematical, computational, physical, and life sciences, and exercised with practical applications and project experiences in a breadth of areas. Our graduates have also demonstrated over the years that EECS provides a strong foundation for those whose work and careers develop in areas quite removed from their origins in engineering.

Undergraduate students in the department take a common core of subjects that serves as their introduction to electrical engineering and computer science, and then systematically build up broad foundations and depth in selected intellectual theme areas that match their individual interests. Laboratory subjects, independent projects, and research provide engagement with principles and techniques of analysis, design, and experimentation in a variety of fields. The department also offers a range of programs that enable students to gain experience in industrial settings, ranging from collaborative industrial projects done on campus to term-long experiences at partner companies.

Graduate study in the department moves students towards mastery of areas of individual interest, through course work and significant research, often defined in interdisciplinary areas that take advantage of the tremendous range of faculty expertise in the department and, more broadly, across MIT.

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, or desiring preprofessional study in these fields, 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 (6-1) is for students specializing in electrical science and engineering, a second (6-2) for those specializing in computer science and engineering, and a third (6-3) for those whose interests cross this traditional boundary. For interested and qualified students, the principal departmental professional program (6-P) 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 one of the three bachelor’s programs.

The Master of Engineering program is being revised, and the new program will be specified in the 2009–2010 Bulletin. The specification below is for the current Master of Engineering degree, which builds on the bachelor’s degree requirements for students in the department who entered MIT prior to fall 2007.

The 6-A Master of Engineering Thesis Program with Industry combines the professional Master of Engineering academic program with periods of industrial practice at affiliated companies. This program is described in more detail below. A Minor in Biomedical Engineering is also available.

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. For undergraduates in the department who entered MIT prior to fall 2007, 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, 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 program 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.
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

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 [satisfied by the mathematics requirement in the Departmental Program]</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement [satisfied by 6.01 and 6.02 together 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>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></td>
</tr>
</tbody>
</table>

Required Subjects  
| 36 |

Restricted Electives  
| 132–144 |

1. Two mathematics subjects (also satisfies REST requirement):  
(a) Either 18.03 or 18.06 (alternatively 18.700)  
(b) Either 6.041 (alternatively 18.440) or 6.042. Students in Course 6-1 must select 6.041 (or 18.440); students in Course 6-3 must select 6.042.

2. One department laboratory:  
One subject selected from the undergraduate laboratory subjects 6.100–6.182. Students in Course 6-3 must select from a departmental list of computer science laboratory subjects. Students in Course 6-1 or 6-2 who take both 6.021 and 6.022 may use 6.022 to satisfy the department laboratory requirement.

3. Three/four foundation subjects:  
(a) Students in Course 6-1 must take three subjects from the EE foundation list: 6.002, 6.004, 6.007.  
(b) Students in Course 6-3 must take the three subjects in the CS foundation list: 6.004, 6.005, 6.006.  
(c) Students in Course 6-2 must take four subjects from the ECE foundation list (6.002–6.007), with two chosen from the EE foundation list and two from the CS foundation list (6.004 may be counted under either EE or CS).

4. Three header subjects:  
(a) Students in Course 6-1 must take three subjects from the EE header list: 6.011, 6.012, 6.013, 6.021.  
(b) Students in Course 6-3 must take the three subjects in the CS header list: 6.033, 6.034, 6.046.  
(c) Students in Course 6-2 must take three subjects from the ECE header list (6.011, 6.012, 6.013, 6.021, 6.033, 6.034, 6.046), with at least one chosen from the EE header list and at least one from the CS header list.

5. Two advanced undergraduate subjects:  
Two subjects from a departmental list of advanced undergraduate subjects.

To complete the required Communication-Intensive subjects in the major, students must take one of the following CI-M subjects as a restricted elective in categories 2 or 4 above by the end of the third year: 6.021, 6.033, 6.101, 6.111, 6.115, 6.1211, 6.131, 6.141, 6.1521, 6.161, 6.182, or 6.805. 6.1UAT/6.UAP constitutes the second CI-M.

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

Unrestricted Electives  
| 48 |

Total Units Beyond the GIRs Required for SB Degree  
| 180–192 |

No subject can be counted both as part of the 12-subject GIRs and as part of the 180–192 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 descriptions.  
For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.  

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. Theses based on group projects in which each participant has an identified responsibility are encouraged.

The four-year preprofessional programs leading to an accredited Bachelor of Science degree are shorter and less comprehensive than the Master of Engineering program. 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 will provide this experience for students receiving both degrees simultaneously.

The bachelor’s programs are structured to provide early, hands-on engagement with ideas, activities, and learning that allow students to experience the range and power of electrical engineering and computer science in an integrated way. The required introductory core subjects, 6.01 followed by 6.02, both involve substantial work in the laboratory, and each carries six units of Institute Lab credit. These are complemented by two mathematics subjects (6.041 or 6.042, also 18.03 or 18.06) and followed by a choice of three or four foundation courses (depending on which bachelor’s program is selected) from a set of subjects that provide the basis for subsequent specialization. Students define their specialization by selecting three header subjects, a department laboratory subject, and two
advanced undergraduate subjects from a quite extensive set of possibilities, and also carry out an advanced undergraduate project. Combining these with the General Institute Requirements and free electives permits students considerable latitude in shaping their program to match diverse interests, while ensuring depth and mastery in a few selected areas.

Much flexibility is built into the elective structure for the department’s programs. In addition, 48 units of totally unrestricted electives are included in every bachelor’s and 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 to 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 preparation seeking a master’s level experience in EECS at MIT should 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 Master of Engineering Thesis Program with Industry 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 usually

<table>
<thead>
<tr>
<th>Master of Engineering in Electrical Engineering and Computer Science/ Course 6-P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>See Notes on Master of Engineering and Bachelor’s Degree Programs</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</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 6.002 and 18.03 in the Departmental Program]</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
</tbody>
</table>

| Total GIR Subjects Required for SB and MEng Degrees | 17 |

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

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

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.001 Structure and Interpretation of Computer Programs, 15 (ED 4), REST</td>
<td>99</td>
</tr>
<tr>
<td>6.002 Circuits and Electronics, 12 (ED 4), REST; Physics II (GIR)<em>, 18.03</em></td>
<td></td>
</tr>
<tr>
<td>6.003 Signals and Systems, 12 (ED 4); 6.002*</td>
<td></td>
</tr>
<tr>
<td>6.004 Computer Structures, 12 (ED 4); 6.001, 6.002; or 6.02</td>
<td></td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>6.19J and 6.1UAP Undergraduate Advanced Project, 12 (ED 0-12)</td>
<td></td>
</tr>
<tr>
<td>6.7ThM MEng Program Thesis, 24 (ED 0-24)**</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Restricted Electives</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Three of the following mathematics subjects, including 6.041 (alternatively 18.440) or 6.042 or 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.</td>
<td>156</td>
</tr>
<tr>
<td>6.041 Probabilistic Systems Analysis, 12, REST; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>(or 18.440 Probability and Random Variables, 12; Calculus II (GIR))</td>
<td></td>
</tr>
<tr>
<td>6.042 Mathematics for Computer Science, 12; Calculus I (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.04 Complex Variables with Applications, 12; Calculus II (GIR), 18.03*</td>
<td></td>
</tr>
<tr>
<td>(or 18.075 Advanced Calculus for Engineers, 12; Calculus II (GIR), 18.03*)</td>
<td></td>
</tr>
<tr>
<td>18.06 Linear Algebra, 12, REST; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>(or 18.700 Linear Algebra, 12, REST; Calculus II (GIR))</td>
<td></td>
</tr>
<tr>
<td>18.085 Computational Science and Engineering I, 12; Calculus II (GIR), 18.03*</td>
<td></td>
</tr>
<tr>
<td>18.086 Computational Science and Engineering II, 12; Calculus II (GIR), 18.03*</td>
<td></td>
</tr>
<tr>
<td>18.100 Analysis I, 12; Calculus II (GIR), 18.03*</td>
<td></td>
</tr>
<tr>
<td>18.311 Principles of Applied Mathematics, 12; Calculus II (GIR), 18.03*</td>
<td></td>
</tr>
<tr>
<td>18.330 Introduction to Numerical Analysis, 12; Calculus II (GIR), 18.03*</td>
<td></td>
</tr>
<tr>
<td>18.353 Nonlinear Dynamics I: Chaos, 12; 18.03, Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.703 Modern Algebra, 12; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.781 Theory of Numbers, 12</td>
<td></td>
</tr>
<tr>
<td>2. One 12-unit subject selected from the undergraduate laboratory subjects 6.100–6.182, 6-1 and 6-2 students who take both 6.022 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.</td>
<td></td>
</tr>
<tr>
<td>3. A total of nine subjects from the lists of engineering concentrations, as follows:</td>
<td></td>
</tr>
<tr>
<td>(a) A large concentration consisting of a header and two other subjects from a single engineering concentration</td>
<td></td>
</tr>
<tr>
<td>(b) Two small concentrations, each consisting of a header and one other subject from a single engineering concentration</td>
<td></td>
</tr>
<tr>
<td>(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.</td>
<td></td>
</tr>
<tr>
<td>Every approved degree program must be arranged so as to satisfy the requirements of one of the three bachelor’s degree programs applicable to students entering MIT prior to fall 2007, by including the following:</td>
<td></td>
</tr>
<tr>
<td>(a) For Course 6-1, three headers from any of the four EE concentrations (bioelectrical engineering; communication, control, and signal processing; devices, circuits and systems; and electrodynamics and energy systems) and also 6.041.</td>
<td></td>
</tr>
<tr>
<td>(b) For Course 6-3, the three headers from the CS concentrations (artificial intelligence and applications, computer systems and architecture, and theoretical computer science) and also 6.042 and 6.170.</td>
<td></td>
</tr>
<tr>
<td>(c) For Course 6-2, two headers from the EE concentrations and two headers from the CS concentrations.</td>
<td></td>
</tr>
</tbody>
</table>
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
6.345, 6.825, 6.831, 6.832, 6.833, 6.834†, 6.835, 6.836, 6.838, 6.839, 6.863†, 6.862, 6.865,


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.

6.021 Quantitative Physiology: Cells and Tissues

Undergraduate
6.022†, 6.024†, 6.025†, 6.801, 9.35

Graduate H-level

Appropriate graduate H-level Course 7, Course 9, Course 20, and HST subjects.

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

*No longer offered, but may be used if taken in previous years.
Electrodynamics and Energy Systems
This concentration concerns the applications of Maxwell’s equations and the Lorentz force law to quasistatic and electrodynamics 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.

Graduate H-level

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.

Undergraduate
6.044l, 6.045l, 6.047, 18.433

6-A Master of Engineering Thesis Program with Industry
The 6-A Master of Engineering Thesis Program with Industry 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, culminating with a Master of Engineering thesis performed at a 6-A member company. Collectively, the participating companies 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 program is primarily designed to work in conjunction with the department’s five-year Master of Engineering degree program. Internship students generally complete three assignments with their cooperating company—usually two summers and one regular term. While on 6-A assignment, students receive pay from the participating company as well as academic credit for their work. During their graduate year, 6-A students generally receive a 6-A fellowship or a research or teaching assistantship to help pay for the graduate year.

Substantial changes were made in 2006 to the 6-A program, with a new fall recruitment during which juniors who wish to work toward an industry-based Master of Engineering thesis may apply for admission to the 6-A program. 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, which is the 6-A version of the department’s five-year 6-P Master of Engineering degree program. 6-PA students do their Master of Engineering thesis at their participating company’s facilities. They can apply up to 36 units of work-assign-
ment credit toward their Master of Engineering degree. Thus, completing the Master of Engineering program need not take longer under 6-PA than under the 6-P program.

The first 6-A assignment may be used for the advanced undergraduate project that is required for award of a bachelor’s degree, by including a written report and obtaining approval by a faculty member.

At the conclusion of their program, 6-A 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 Master of Engineering Thesis Program with Industry is available at the 6-A Office, Room 38-409E, 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 to two 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 to five years beyond the master’s level.

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 communications, control, signal processing, and optimization; computer science; artificial intelligence, robotics, computer vision, and graphics; electronics, computers, systems, and networks; electromagnetics and electrodynamics; optics, photonics, and quantum electronics; energy conversion devices and systems; power engineering and power electronics; materials and devices; VLSI system design and technology; nanoelectronics; bioelectrical engineering; and computational biology.

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. Numerous 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. Descriptions of many of these laboratories may be found under 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 of previous degree (bachelor’s or master’s), 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 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.

Electrical Engineer or Engineer in Computer Science

The general requirements for an engineer’s degree are given under 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 under 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. Students who have received a bachelor’s degree outside the department, 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.

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, but 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, 617-253-4605, or http://www-eecs.mit.edu/.

Other Degree Programs

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 under Interdisciplinary Graduate Programs in Part 2.

Computation for Design and Optimization

The Computation for Design and Optimization (CDO) program offers a master’s degree to students interested in the analysis and application of computational approaches to designing and operating engineered systems. The curriculum is designed with a common core serving all engineering disciplines and an elective component focusing on specific applications. Current MIT graduate students may pursue a CDO master’s degree in conjunction with a department-based master’s or PhD program. For more information, see the full program description under Interdisciplinary Graduate Programs or visit http://web.mit.edu/cdo-program/index.html.

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 under Engineering Systems Division.

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 from a participating engineering department. The program is offered jointly through the MIT Sloan School of Management and the School of Engineering. For more information, see the program description under Engineering Systems Division 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 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 Engineering Systems Division or visit http://tppserver.mit.edu/.

Faculty and Staff

Faculty and Teaching Staff

William Eric Leifur Grimsson, PhD
Bernard M. Gordon Professor of Medical Engineering
Department Head
Duane S. Boning, PhD
Professor of Electrical Engineering and Computer Science
Associate Head
Srinivas Devadas, PhD
Professor of Electrical Engineering and Computer Science
Associate Head

George C. Verghese, PhD
Professor of Electrical Engineering
Education Officer

Arthur Clarke Smith, PhD
Professor of Electrical Engineering
Undergraduate Officer

Terry Philip Orlando, PhD
Professor of Electrical Engineering
Graduate Officer

Markus Zahn, ScD
Thomas and Gerd Perkins Professor of Electrical Engineering
Director, 6-A Internship Program

Professors

Harold Abelson, PhD
Class of 1922 Professor of Computer Science and Engineering

Anant Agarwal, PhD
Professor of Computer Science and Engineering
Associate Director, Computer Science and Artificial Intelligence Laboratory

Akintunde I. Akinwande, PhD
Professor of Electrical Engineering

Dimitri A. Antoniadis, PhD
Ray and Maria Stata Professor of Electrical Engineering

Arvind, PhD
Professor of Computer Science and Engineering

Charles W. and Jennifer C. Johnson Professor of Computer Science and Engineering

Arthur Bernard Baggeroer, ScD
Ford Professor of Engineering and Mechanical Engineering

Hari Balakrishnan, PhD
Professor of Computer Science and Engineering

Abraham Bers, ScD
Professor of Electrical Engineering

Dimitri P. Bertsekas, PhD
McAfee Professor of Electrical Engineering

Robert Cregar Berwick, PhD
Professor of Computer Science and Engineering and Computational Linguistics

Sangeeta Bhatia, MD, PhD
Professor of Electrical Engineering and Health Sciences and Technology
Howard Hughes Medical Institute Investigator

Louis Benjamin Daniel Braida, PhD
Henry Ellis Warren Professor of Electrical Engineering and Health Sciences and Technology

Rodney Allen Brooks, PhD
Panasonic Professor of Computer Science and Engineering

Vincent W. S. Chan, PhD
Joan and Irwin M. Jacobs Professor of Electrical Engineering

Anantha P. Chandrakasan, PhD
Joseph F. and Nancy P. Keithley Professor of Electrical Engineering
Director, Microsystems Technology Laboratories

Munther A. Dahleh, PhD
Professor of Electrical Engineering

Randall Davis, PhD
Professor of Computer Science and Engineering

Jesús A. del Alamo, PhD
Donner Professor of Electrical Engineering
Associate Director, Microsystems Technology Laboratories

MacVicar Faculty Fellow

Mildred Spiewak Dresselhaus, PhD
Professor of Electrical Engineering and Physics

Clifton G. Fonstad, Jr., PhD
Vitesse Professor of Electrical Engineering

Dennis M. Freeman, PhD
Professor of Electrical Engineering
MacVicar Faculty Fellow

William T. Freeman, PhD
Professor of Computer Science and Engineering

James G. Fujimoto, PhD
Professor of Electrical Engineering

Robert Gray Gallager, ScD
Professor of Electrical Engineering

David K. Gifford, PhD
Professor of Computer Science and Engineering

Shafrira Goldwasser, PhD
RSA Professor of Computer Science and Engineering

Martha L. Gray, PhD
Edward Hood Taplin Professor of Medical and Electrical Engineering

Paul Edward Gray, ScD
Professor of Electrical Engineering

Alan Jay Grodzinsky, PhD
Professor of Electrical, Mechanical, and Biological Engineering
Director, Center for Biomedical Engineering

John V. Guttag, PhD
Dugald C. Jackson Professor of Computer Science and Engineering

Frederick Clair Hennie III, ScD
Professor of Computer Science and Engineering

Berthold Klaus Paul Horn, PhD
Professor of Computer Science and Engineering

Judy L. Hoyt, PhD
Professor of Electrical Engineering
Associate Director, Microsystems Technology Laboratories

Qing Hu, PhD
Professor of Electrical Engineering

Erich Peter Ippen, PhD
Elizu Thomson Professor of Electrical Engineering and Physics

Tommi S. Jaakkola, PhD
Professor of Computer Science and Engineering

David R. Karger, PhD
Professor of Computer Science and Engineering

John Gabriel Kassakian, ScD
Professor of Electrical Engineering

Director, Laboratory for Electromagnetic and Electronic Systems

James Logan Kirtley, Jr., PhD
Professor of Electrical Engineering

2008–2009
Cardinal Warde, PhD
Professor of Electrical Engineering

Jacob K. White, PhD
Cecil H. Green Professor of Electrical Engineering

Alan Steven Willsky, PhD
Edwin S. Webster Professor of Electrical Engineering

Gerald Loomis Wilson, ScD
Vannevar Bush Professor of Electrical and Mechanical Engineering

Patrick Henry Winston, PhD
Ford Professor of Engineering

Gregory W. Wornell, PhD
Professor of Electrical Engineering

John L. Wyatt, Jr., PhD
Professor of Electrical Engineering

Victor W. Zue, ScD
Delta Electronics Research Professor of Electrical Engineering and Computer Science

Director, Computer Science and Artificial Intelligence Laboratory

Associate Professors

Elfar Adalsteinsson, PhD
Associate Professor of Electrical Engineering and Computer Science and Health Sciences and Technology

Saman P. Amarasinghe, PhD
Associate Professor of Computer Science and Engineering

Marc A. Baldo, PhD
Associate Professor of Electrical Engineering

Regina A. Barzilay, PhD
Douglas T. Ross Career Development Associate Professor of Computer Science and Engineering

Karl K. Berggren, PhD
Emanuel E. Landsman Associate Professor of Electrical Engineering and Computer Science

Vladimir Bulovic, PhD
Associate Professor of Electrical Engineering

Issac L. Chuang, PhD
Associate Professor of Electrical Engineering

Michael J. Collins, PhD
Associate Professor of Computer Science and Engineering

Luca Daniel, PhD
Emanuel E. Landsman Career Development Associate Professor of Electrical Engineering

Trevor Darrell, PhD
Associate Professor of Computer Science and Engineering

Erik D. Demaine, PhD
Associate Professor of Computer Science and Engineering

Frederic P. Durand, PhD
Associate Professor of Computer Science and Engineering

Michael D. Ernst, PhD
Associate Professor of Computer Science

Polina Golland, PhD
Distinguished Alumnus 1964 Career Development Associate Professor of Computer Science and Engineering

Vivek K. Goyal, PhD
Esther and Harold Edgerton Career Development Associate Professor of Electrical Engineering and Computer Science

Peter L. Hagelstein, PhD
Associate Professor of Electrical Engineering

Jongyoon Han, PhD
Associate Professor of Electrical Engineering and Biological Engineering

Piotr Indyk, PhD
Associate Professor of Computer Science and Engineering

Dina Katabi, PhD
Class of 1947 Career Development Associate Professor of Computer Science and Engineering

Manolis Kellis, PhD
Van Tassel Career Development Associate Professor of Electrical Engineering and Computer Science

Samuel R. Madden, PhD
Associate Professor of Computer Science and Engineering

Robert C. Miller, PhD
NBX Career Development Associate Professor of Computer Science and Engineering

Robert T. Morris, PhD
Associate Professor of Computer Science and Engineering

Asuman E. Ozdaglar, PhD
Class of 1943 Career Development Associate Professor of Electrical Engineering

David J. Perreault, PhD
Associate Professor in Power Engineering

Michael H. Perrott, PhD
Associate Professor in Power Engineering

Jovan Popovic, PhD
Associate Professor of Computer Science and Engineering

Rahul Sarpeshkar, PhD
Associate Professor of Electrical Engineering

Collin M. Stultz, PhD, MD
W.M. Keck Career Development Associate Professor of Electrical Engineering and Computer Science, and Health Sciences and Technology

Antonio Torralba, PhD
Associate Professor of Electrical Engineering and Computer Science

Joel Voldman, PhD
Associate Professor of Electrical Engineering

Lizhong Zheng, PhD
Steven and Renee Finn Associate Professor of Electrical Engineering

Assistant Professors

Scott Aaronson, PhD
Assistant Professor of Electrical Engineering and Computer Science

Constantinos Daskalakis, PhD
Assistant Professor of Computer Science and Engineering

Joel L. Dawson
Assistant Professor of Electrical Engineering

Jing Kong, PhD
ITT Career Development Assistant Professor of Electrical Engineering

Tomás Palacios, PhD
Assistant Professor of Electrical Engineering
Devavrat Shah, PhD
Jamieson Career Development Assistant
Professor of Electrical Engineering and Computer Science

Vladimir M. Stojanovic, PhD
Assistant Professor of Electrical Engineering and Computer Science

Russell L. Tedrake, PhD
X-Consortium Assistant Professor of Computer Science and Engineering

Mehmet Fatih Yanik, PhD
Robert J. Shillman Career Development Assistant
Professor of Electrical Engineering

Research Staff

Senior Research Scientists
David D. Clark, PhD
Thomas Frederic Knight, Jr., PhD

Research Affiliates
Elmer C. Lupton, PhD
Sheila Prasad, PhD
Bruce D. Wedlock, ScD

Postdoctoral Lecturer
Shivani Agarwal, PhD

Professors Emeriti
Michael Athans, PhD
Professor of Electrical Engineering, Emeritus

Amar Gopal Bose, ScD
Professor of Electrical Engineering, Emeritus

James Donald Bruce, ScD
Professor of Electrical Engineering, Emeritus

Fernando José Corbató, PhD
Professor of Computer Science and Engineering, Emeritus

Jack Bonnell Dennis, ScD
Professor of Computer Science and Engineering, Emeritus

Murray Eden, PhD
Professor of Electrical Engineering, Emeritus

David Jacob Epstein, ScD
Professor of Electrical Engineering, Emeritus

Shaoul Ezekiel, ScD
Professor of Aeronautics and Astronautics and Electrical Engineering, Emeritus

Robert Mario Fano, ScD
Ford Professor of Engineering, Emeritus

Lawrence Samuel Frishkopf, PhD
Professor of Electrical and Bioengineering, Emeritus

Harry Constantine Gatos, PhD
Professor of Molecular Engineering and Electronic Materials, Emeritus

Leonard A. Gould, ScD
Professor of Electrical Engineering, Emeritus

Carl Eddie Hewitt, PhD
Associate Professor of Computer Science and Engineering, Emeritus

Robert Spyde Kennedy, ScD
Professor of Electrical Engineering, Emeritus

Francis Fan Lee, PhD
Professor of Electrical Engineering and Computer Science, Emeritus

Jerome Ysrael Lettvin, MD
Professor of Electrical and Bioengineering and Communications Physiology, Emeritus

Alan Louis McWhorter, ScD
Professor of Electrical Engineering, Emeritus

Frederic Richard Morgenthaler, PhD
Professor of Electrical Engineering, Emeritus

Walter E. Morrow, Jr., MS
Professor of Electrical Engineering, Emeritus

George Woodman Pratt, Jr., PhD
Professor of Electrical Engineering, Emeritus

Jack Philip Ruina, DEE
Professor of Electrical Engineering, Emeritus

Jerome H. Saltzer, ScD
Professor of Computer Science and Engineering, Emeritus

William Francis Schreiber, PhD
Professor of Electrical Engineering, Emeritus

Campbell Leach Searle, SM
Professor of Electrical Engineering, Emeritus

Stephen David Senturia, PhD
Professor of Electrical Engineering, Emeritus

William McConway Siebert, ScD
Ford Professor of Engineering, Emeritus

Louis Dijour Smullin, SM
Professor of Electrical Engineering, Emeritus

Richard Douglas Thornton, ScD
Professor of Electrical Engineering, Emeritus

Thomas Fischer Weiss, PhD
Professor of Electrical and Bioengineering, Emeritus

David Calvin White, PhD
Ford Professor of Engineering, Emeritus

John McReynolds Wozencraft, PhD
Professor of Electrical Engineering, Emeritus
The MIT Engineering Systems Division (ESD) embraces complex, large-scale problems utilizing faculty from all academic departments in the School of Engineering as well as faculty from the MIT Sloan School of Management and the School of Humanities, Arts, and Social Sciences. The mission of ESD is to pursue the study, analysis, and design of complex systems involving technology, people, and services within their broader environmental, financial, legal, organizational, social, and political contexts. Researching engineering systems often draws upon state-of-the-art knowledge in engineering management, and the social sciences. MIT established the division in 1999 with the charter to develop academic and research programs that educate future leaders in our technological age; to serve as a model to broaden engineering education generally; and to expand the scope and practice of engineering. To help accomplish these goals, ESD actively develops innovative relationships with industry and government through collaborative global research projects and long-distance educational programs.

Designing engineering systems is increasingly difficult as they increase in size, scope, and complexity. The rate of change is increasing, often due to forces of globalization, new technological capabilities, rising consumer expectations, and increasing social awareness. Purely technical approaches to analysis and design of these systems often lead to failure, as a more comprehensive approach is required. Consequently, knowledgeable development of engineering systems calls for new frameworks of analysis and design that are broader than those of the traditional single-discipline paradigms of individual engineering departments. 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. While the ESD approach is broader, it must also retain the depth associated with the traditional single-discipline approach. ESD is founded on the recognition that new approaches, frameworks, and theories—both broad and deep—must be developed to analyze and design these systems.

The Engineering Systems Division offers four professional master’s 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 core educational and research activity of ESD is the doctoral program in engineering systems, which prepares students for careers in academia, industry, and government. ESD 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, the Center for Transportation and Logistics, the Center for Engineering Systems Fundamentals, and the MIT-Portugal Program.

ESD’s educational and research programs are deeply involved with industry, government, and engineering practice in general. Units within ESD have many, often novel, relationships with industry. Examples include: consortia formed around the International Motor Vehicle and the Lean Advancement programs in the Center for Technology, Policy, and Industrial Development; the Center for Transportation and Logistics’ Supply Chain Exchange, the Integrated Supply Chain Management Program, and the Age Lab; and corporate partnerships of the Leaders for Manufacturing and the System Design and Management programs.

Application forms for all programs can be accessed 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 registering at http://www.ielts.org/ for the International English Language Testing System (IELTS) exam, academic format, and achieving a score of 7.5 or better. In areas where the IELTS is not available, the Test of English as a Foreign Language (TOEFL) is an acceptable substitute, if a score equal to or higher than 255 for the computer-based test, 103 for the internet-based test, and 610 for the paper-based test, is achieved. 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 the Master of Engineering in Logistics may offer student fellowships or graduate research or teaching assistantships. Information about these should be obtained directly from the individual programs.

For details, please refer to ESD’s Academic Office (esdgrad@mit.edu) and to the MIT Sloan School of Management for programs offering joint degrees.

MASTER’S PROGRAMS

Master of Science in Technology and Policy
Students who wish 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 US 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 to or higher than 255 (610 for the paper-based version, or 103 for the internet-based test [iBT]). 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

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 industry experience, but is open to anyone who 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 the paper-based version, or 103 for the internet-based version).

The MLOG curriculum begins in September. There are two admission rounds. The round 1 deadline is January 16, 2009; the round 2 deadline is April 3, 2009. 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 technical professionals who seek to build upon their backgrounds and experience in order to 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 learning instruction for technical professionals 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 three track options for SDM students: system design, product development, and IT/software systems. 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 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 product development professional, 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 fellows may apply via the web at [http://sdm.mit.edu/apply.html](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/](http://sdm.mit.edu/).

Leaders for Manufacturing

The Leaders for Manufacturing (LFM) program is an educational and research partnership among 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 and operations.

The LFM program leads to two MIT master’s degrees, an SM from ESD (or another participating engineering department) and an MBA or SM from the MIT 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 6.5-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 MIT Sloan School of Management. All applicants must take the GRE. Alternatively, anyone applying through Sloan may choose to take the GMAT.

For additional information, visit [http://lfm.mit.edu/](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 MIT Sloan School of Management.

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 focuses on the design and implementation of socio-technical systems. The ESD SM can be a terminal degree that prepares the student 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 of mutual interest different from those covered by the other SM programs that are part of ESD (i.e., the Technology and Policy, Master of Engineering in Logistics, and System Design and Management programs described elsewhere in this chapter). It can also serve as the engineering SM for students in the Leaders for Manufacturing program.

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 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 member in their field of interest to serve as their thesis advisor. For details, see the Frequently Asked Questions about Admissions at [http://esd.mit.edu/academic/smd_phd_faqs.html](http://esd.mit.edu/academic/smd_phd_faqs.html).

The ESD Education Committee makes admissions decisions once a year. Applications are due January 10. For additional information, please visit [http://esd.mit.edu/academic/ms.html](http://esd.mit.edu/academic/ms.html) first. To resolve subsequent issues, contact the ESD Academic Office at 617-253-1182 or esdgrad@mit.edu.

Doctoral Program

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 participants 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/phd/](http://esd.mit.edu/phd/)). All candidates take a doctoral seminar (ESD.83) and ESD.86 Models, Data, and Inference for Socio-Technical Systems, and choose one of several subjects in social science research methods. Beyond the basics, each doctoral student takes a sequence of additional in-depth 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 jointly 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.

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. The time required for the ESD PhD is three to 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 before graduating.

Admission to the ESD PhD program is based upon outstanding academic performance in engineering or applied science, standardized test scores on the GRE and TOEFL, demonstrable interest in engineering systems as a field of study, and letters of recommendation. Current MIT students wishing to apply to the ESD PhD program 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/academic/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 http://esd.mit.edu/phd/ first, and see the Frequently Asked Questions about Admissions at http://esd.mit.edu/academic/sm_phd_faq.html. To resolve subsequent issues, contact the ESD Academic Office at 617-253-1182 or esdgrad@mit.edu.

**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 socio-technical 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 Ford-MIT Alliance, IMVP, Lean Advancement Initiative, 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 (MIT-CTL) has been a world leader in supply chain management and transportation education and research. MIT-CTL 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. MIT-CTL has three main research programs: Supply Chain Management and Logistics, Transportation, and the MIT AgeLab.

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

- Carbon Efficient Supply Chains
- Demand Management
- Freight Transportation Management
- Healthcare Supply Chain
- Scenario Planning
- Strategy Alignment
- Supply Chain 2020: The Future of the Supply Chain
- Supply Chain Innovation in Emerging Markets
- Supply Chain Security
- Supply Chain Network Risk Management
- Supply Chain Network Risk Management

MIT-CTL research in the area of transportation spans all of its aspects and modes. Research projects include:

- New England University Transportation Center
- MIT/Transit Professional Development Program
- MIT Program in Intelligent Transportation Systems
- National Center of Excellence for Aviation Operations Research

The AgeLab brings together a multidisciplinary team from across MIT and around the world to conduct research on health and wellness, transportation, and longevity planning to develop new ideas and technologies that improve the quality of life for older adults and the people who care for them.
**Outreach**
The gateway to the center’s research is MIT-CTL’s Corporate Outreach Program. Through this multifaceted program, industry and MIT-CTL collaborate to turn innovative research into market-winning commercial applications. The center currently has more than 45 corporate partners worldwide who participate in its events, interact with its researchers, and contribute to and help steer its research projects.

**Education**
In education, MIT is consistently ranked first among business programs in logistics and supply chain management. MIT-CTL graduate degrees and executive-level programs are unsurpassed for quality and market relevance.

MIT-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. The MLOG program is described under Master’s Programs earlier in this chapter.

An ESD doctoral program can be focused on logistics and supply chain management as well. Through MIT-CTL, MIT is the lead university in Federal Region I of the University Transportation Centers program administered by the US Department of Transportation. Through this program, full and partial fellowships are awarded to graduate students in transportation. Research and teaching assistantships also are available through this and other programs. 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, MIT Center for Transportation and Logistics, Room E40-275, caplice@mit.edu, or visit [http://web.mit.edu/ctl/](http://web.mit.edu/ctl/).

Students interested in the Master of Science in Transportation program administered through the Department of Civil and Environmental Engineering should contact Nigel Wilson, Room 1-238, 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.

**Faculty and Staff**

**Faculty and Teaching Staff**
Yossi Sheffi, PhD
Professor of Engineering Systems and Civil and Environmental Engineering
Director, MIT Center for Transportation and Logistics
Director, Engineering Systems Division

Olivier L. de Weck, PhD
Associate Professor of Aeronautics and Astronautics and Engineering Systems
Associate Director, Engineering Systems Division

**Professors**
Thomas J. Allen, PhD
Howard W. Johnson Professor of Management, Emeritus
Professor of Engineering Systems, Emeritus
Codirector, LFM and SDM Programs

George E. Apostolakis, PhD
Korea Electric Power Professor of Nuclear Science and Engineering
Professor of Engineering Systems

Cynthia Barnhart, PhD
Professor of Civil and Environmental Engineering and Engineering Systems
Codirector, Operations Research Center
Associate Dean for Academic Affairs, School of Engineering

John Carroll, PhD
Morris A. Adelman Professor of Management
Professor of Engineering Systems
Codirector, Lean Advancement Initiative

Joel Philip Clark, ScD
Professor of Materials Systems and Engineering Systems

Edward F. Crawley, PhD
Professor of Aeronautics and Astronautics and Engineering Systems
Ford Professor of Engineering

Michael Cusumano, PhD
Sloan Management Review Distinguished Professor of Management
Professor of Engineering Systems

Richard de Neufville, PhD
Professor of Civil and Environmental Engineering and Engineering Systems

Thomas Waddy Eagar, ScD
Thomas Lord Professor of Materials Engineering and Engineering Systems

Steven D. Eppinger, ScD
General Motors LFM Professor of Management Science
Professor of Engineering Systems
Deputy Dean, MIT Sloan School of Management

Charles Fine, PhD
Chrysler LFM Professor of Management
Professor of Engineering Systems

Stephen C. Graves, PhD
Abraham J. Siegel Professor of Management
Professor of Engineering Systems

John Hansman, PhD
Professor of Aeronautics and Astronautics and Engineering Systems
Head, Division of Humans and Automation
Director, International Center for Air Transportation

David Edgar Hardt, PhD
Ralph E. and Eloise F. Cross Professor of Mechanical Engineering
Professor of Engineering Systems

Daniel Hastings, PhD
Professor of Aeronautics and Astronautics and Engineering Systems
Dean for Undergraduate Education

Thomas Lord Professor of Materials Engineering
Professor of Engineering Systems

Paul A. Lagacé, PhD
General Motors LFM Professor of Management
Professor of Engineering Systems

Richard Larson, PhD
Mitsui Professor of Civil and Environmental Engineering and Engineering Systems
MacVicar Faculty Fellow

Richard de Neufville, PhD
Professor of Civil and Environmental Engineering and Engineering Systems

Nancy Leveson, PhD
Professor of Aeronautics and Astronautics and Engineering Systems

Olivier L. de Weck, PhD
Professor of Engineering Systems
Codirector, LFM and SDM Programs
Seth Lloyd, PhD  
Professor of Mechanical Engineering and Engineering Systems  

Stuart Madnick, PhD  
John Norris Maguire Professor of Information Technology and Engineering Systems  
Codirector, PROFIT Program  

David Hunter Marks, PhD  
Morton and Claire Goulder Family Professor of Civil and Environmental Engineering and Engineering Systems  

David A. Mindell, PhD  
Frances and David Dibner Professor of the History of Engineering and Manufacturing (STS)  
Professor of Engineering Systems  
MacVicar Faculty Fellow  
Director, Science, Technology, and Society Program  

Sanjoy Mitter, PhD  
Professor of Electrical Engineering and Engineering Systems  

Fred Moavenzadeh, PhD  
James Mason Crafts Professor  
Professor of Civil and Environmental Engineering and Engineering Systems  
Director, Technology and Development Program  

Ernest Moniz, PhD  
Cecil and Ida Green Professor of Physics and Engineering Systems  
Director, Laboratory for Energy and the Environment  
Director, MIT Energy Initiative  

Joel Moses, PhD  
Professor of Computer Science and Engineering Systems  
Institute Professor  
Acting Director, Center for Technology, Policy, and Industrial Development  

Dava J. Newman, PhD  
Professor of Aeronautics and Astronautics and Engineering Systems  
MacVicar Faculty Fellow  
Director, Technology and Policy Program  

Daniel Roos, PhD  
Japan Steel Industry Professor of Civil and Environmental Engineering and Engineering Systems  
Director, MIT-Portugal Program  

Warren P. Seering, PhD  
Weber-Shaughness Professor of Mechanical Engineering and Engineering Systems  

David Simchi-Levi, PhD  
Professor of Civil and Environmental Engineering and Engineering Systems  
Codirector, LFM and SDM Programs  

John Sterman, PhD  
Jay W. Forrester Professor of Management  
Professor of Engineering Systems  
Director, Systems Dynamics Group  

Joseph Martin Sussman, PhD  
JR East Professor of Civil and Environmental Engineering and Engineering Systems  

James Utterback, PhD  
David J. McGrath, Jr. (1959) Professor of Management and Innovation  
Professor of Engineering Systems  

Eric von Hippel, PhD  
T. Wilson (1953) Professor of Management  
Professor of Engineering Systems  

John Williams, PhD  
Associate Professor of Civil and Environmental Engineering and Engineering Systems  
Director, Information Engineering, Auto-ID Laboratory  

Dava J. Newman, PhD  
Assistant Professor of Aeronautics and Astronautics and Engineering Systems  

Randolph Kirchain, PhD  
Assistant Professor of Materials Science and Engineering Systems  

Devavrat Shah, PhD  
Assistant Professor of Electrical Engineering and Computer Science and Engineering Systems  

Annalisa Weigel, PhD  
Jerome C. Hunsaker Assistant Professor of Aeronautics and Astronautics and Engineering Systems  

Maria Yang, PhD  
Assistant Professor of Mechanical Engineering and Engineering Systems  

Christopher Magee, PhD  
Professor of the Practice of Engineering Systems and Mechanical Engineering  

Deborah Nightingale, PhD  
Professor of the Practice of Aeronautics and Astronautics and Engineering Systems  
Codirector, Lean Advancement Initiative  

Joseph Coughlin, PhD  
Senior Lecturer, Engineering Systems  
Director, Age Lab and New England University Transportation Center, Center for Transportation and Logistics  

Frank R. Field III, PhD  
Senior Research Associate, CTPID  
Senior Research Engineer, Materials Systems Laboratory  
Senior Lecturer, Engineering Systems  
Director of Education, Technology and Policy Program
Patrick Hale, PhD  
Senior Lecturer, Engineering Systems  
Director, System Design and Management  
Fellows Program

Donna Rhodes, PhD  
Senior Lecturer, Engineering Systems  
Principal Research Scientist, Center for  
Technology, Policy, and Industrial Development

Donald B. Rosenfield, PhD  
Senior Lecturer, Sloan School of Management  
Director, Leaders For Manufacturing Fellows  
Program

Daniel Whitney, PhD  
Senior Lecturer, Engineering Systems and  
Mechanical Engineering  
Senior Research Scientist, Center for Technology,  
Policy, and Industrial Development

**Research Staff**

Christopher Caplice, PhD  
Executive Director, Center for Transportation and  
Logistics and Master of Engineering in Logistics  
Program

Stan N. Finkelstein, MD  
Senior Research Scientist, Engineering Systems  
and Health Sciences and Technology
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 energy, environmental, health, economic, and manufacturing issues relating to materials. Materials science and engineering is a field critical to our future economic and environmental well-being.

Materials science emphasizes the study of the structure of materials and of processing-structure-property relations in 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 atoms or molecules in crystalline or amorphous configurations, or the size, shape, and orientation of 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.

Recent achievements in materials have depended as much on advances in materials engineering as they have on materials science. When developing engineering processes for preparation and production of materials, and when designing materials for specific applications, the materials engineer must understand fundamental concepts such as thermodynamics, and heat and mass transfer and chemical kinetics, and must also have a proper concern for economic, social, and environmental factors.

Today’s materials scientists and engineers are well equipped to address some of the key challenges facing humanity, including energy generation and storage and the environmental impact of human activities, and to improve human health and well-being.

Materials engineering and materials science are intertwined in the department. There are some subjects that all students of materials should know: thermodynamics, kinetics, materials structure, electronic and mechanical properties of materials, bio- and polymeric materials, and materials processing. Core subjects in these areas are offered at the undergraduate and graduate levels. In addition, elective subjects covering a wide range of topics are offered. Lectures are complemented by a variety of laboratory experiments. By selecting appropriate subjects, the student can follow many different paths with emphasis on engineering, science, or a mixture of the two.

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 diverse important positions in the electronics industry, in companies working on energy and the environment, in the aerospace industry, in consumer industries, in biomaterials and medical industries, and in the basic materials preparation and producing industries. A large number of DMSE alumni are faculty members of leading universities.

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 can 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 begin at the beginning of the sophomore year, although it can be started in the spring term of the sophomore year or in the junior year with some loss of scheduling flexibility.

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

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

Participation in laboratory work by undergraduates is an integral part of the curriculum. The departmental core subjects include extensive laboratory exercises, which investigate materials properties, structure, and processing, and are complementary to the lecture subjects. The junior-year core includes a laboratory subject, 3.042, that emphasizes design, teamwork, and communication skills. 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 teaching laboratories containing a wide variety of materials processing and characterization equipment. The Undergraduate Teaching Laboratory on the Infinite Corridor, which opened in 2003, includes facilities for biomaterials research, chemical synthesis, and physical and electronic properties measurement. Other departmental facilities include those for preparation and characterization of thin films, ceramics and glasses, metallic and nonmetallic crystals, biomaterials, and polymers. Equipment is available for the study of mechanical properties in the Nanomechanics Laboratory, and for metal casting and joining in the Foundry. Materials are characterized by optical, electron (TEM, SEM) and scanning probe (AFM, STM) microscopy techniques, diffraction, and spectroscopy, and there is equipment for a wide range 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 (3.01U). 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 and arranged by the department. Together with a company representative, a faculty advisor is assigned to each student to assist as supervisor during his or her work assignments. Students earn a salary during their work periods and also receive academic credit.

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 Course 3 program. For instance, some students may wish to take more biology and chemistry subjects in preparation for medical school, or more management subjects prior to entering an MBA or law program. In these cases, the 3-A program may be of value as a more flexible curriculum in which a larger number of elective choices is available.

The curriculum requirements 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, 18.034; 3.021; 3.016, 1.00, of 6.01; 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, 5.33, 5.36, 5.38, 6.021J/2.791J/20.370J, and 7.02.

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 (Professor David Roylance, roylance@mit.edu), 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 ABET accreditation for the 3-A program.
The program requires that all students take 3.014 Materials Laboratory, 12, LAB, CI-M, as one of the Departmental Program units that also satisfy the gIRs.

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).

### 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 nonindustrial societies by making the natural and engineering sciences part of the archaeological tool kit.

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

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

The HASS Concentration in Archaeology and Archaeological Science provides concentrators with a basic knowledge of the field of archaeology, the systematic study of the human past. Students pursuing the SB in 3-C may not also concentrate in this area. The archaeology and archaeological science concentration consists of four subjects: 3.086, 3.985J, and two other HASS electives from among those currently offered in this subject area: 3.094, 3.982, 3.983, 3.987.

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### Bachelor of Science in Materials Science and Engineering/Course 3

<table>
<thead>
<tr>
<th>General Institute Requirements (gIRs)</th>
<th>Subjects</th>
<th>Science Requirement</th>
<th>Humanities, Arts, and Social Sciences Requirement</th>
<th>Restricted Electives in Science and Technology (REST) Requirement (can be satisfied by 3.012 and 3.021)</th>
<th>Laboratory Requirement (can be satisfied by 3.014 in the Departmental Program)</th>
<th>Total GIR Subjects Required for SB Degree</th>
<th>Communication Requirement</th>
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<tbody>
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<table>
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<tr>
<th>Required Subjects</th>
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<tbody>
<tr>
<td>3.012 Fundamentals of Materials Science and Engineering, 15, REST; 18.03*</td>
</tr>
<tr>
<td>3.014 Materials Laboratory, 12, LAB, CI-M</td>
</tr>
<tr>
<td>One of the following three subjects:</td>
</tr>
<tr>
<td>3.016 Mathematical Methods for Materials Scientists and Engineers, 12; Calculus II (GIR)</td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GIR)</td>
</tr>
<tr>
<td>18.03a Differential Equations, 12, REST; Calculus II (GIR)</td>
</tr>
</tbody>
</table>

| One of the following four subjects: |
| 3.021 Introduction to Modeling and Simulation, 12, REST; 18.03* |
| 1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; Calculus I (GIR) |
| 6.01 Introduction to EECS I, 12, 1/2 LAB; Physics II (GIR) |
| 3.016 Mathematical Methods for Materials Scientists and Engineers, 12; Calculus II (GIR) |
| 3.022 Microstructural Evolution in Materials, 12; 3.012 |
| 3.024 Electronic, Optical, and Magnetic Properties of Materials, 12; 3.012 |
| 3.052 Mechanical Behavior of Materials, 12; Physics I (GIR), 3.016* |
| 3.084 Organic and Biomaterials Chemistry, 12; 3.012 |
| 3.042 Materials Project Laboratory, 12, CI-M; 3.014* |
| 3.044 Materials Processing, 12; 3.012, 3.022 |

| 3.TU Thesis, 9 ** | |
| 3.93 Industrial Practice, 6 |
| 3.931 Industrial Practice, 6 |

<table>
<thead>
<tr>
<th>Restricted Electives **</th>
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</thead>
<tbody>
<tr>
<td>3.016 Mathematical Methods for Materials Scientists and Engineers, 12; Calculus II (GIR)</td>
</tr>
<tr>
<td>3.021 Introduction to Modeling and Simulation, 12, REST; 18.03*</td>
</tr>
<tr>
<td>3.046 Thermodynamics of Materials, 12, REST; 18.03*</td>
</tr>
<tr>
<td>3.048 Advanced Materials Processing, 12; 3.022, 3.044</td>
</tr>
<tr>
<td>3.051 Materials for Biomedical Applications, 12; Chemistry (GIR), Biology (GIR), 3.012*, 5.60*</td>
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<tr>
<td>3.052 Nanomechanics of Materials and Biomaterials, 12; 3.012*</td>
</tr>
<tr>
<td>3.053 Molecular, Cellular, and Tissue Biomechanics, 12; 18.03*, Biology (GIR), 2.370*</td>
</tr>
<tr>
<td>3.063 Polymer Physics, 12; 3.012</td>
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<tr>
<td>3.064 Polymer Engineering, 12; 3.012, 3.044</td>
</tr>
<tr>
<td>3.07 Introduction to Ceramics, 12; 3.012</td>
</tr>
<tr>
<td>3.072 Symmetry, Structure, and Tensor Properties of Materials, 12; 3.016*</td>
</tr>
<tr>
<td>3.073 Diffraction and Structure, 12; 18.03, 3.024</td>
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<tr>
<td>3.074 Imaging of Materials, 12; 3.024*</td>
</tr>
<tr>
<td>3.08 Economic and Environmental Materials Selection, 12; 3.012*</td>
</tr>
<tr>
<td>3.14 Physical Metallurgy, 12; 3.012, 3.022, 3.032</td>
</tr>
<tr>
<td>3.15 Electrical, Optical, and Magnetic Materials and Devices, 12; 3.024</td>
</tr>
<tr>
<td>3.155 Nanoscale Materials, 12; 3.024</td>
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<tr>
<td>3.155J Micro/Nano Processing Technology, 12, CI-M; permission of instructor</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Departmental Program Units That Also Satisfy the gIRs</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.014 Materials Laboratory, 12, LAB, CI-M</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Unrestricted Electives</th>
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<tbody>
<tr>
<td>48</td>
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**Units**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.012 Fundamentals of Materials Science and Engineering, 15, REST; 18.03*</td>
<td>128–138</td>
</tr>
<tr>
<td>3.014 Materials Laboratory, 12, LAB, CI-M</td>
<td></td>
</tr>
<tr>
<td>One of the following three subjects:</td>
<td></td>
</tr>
<tr>
<td>3.016 Mathematical Methods for Materials Scientists and Engineers, 12; Calculus II (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>18.03a Differential Equations, 12, REST; Calculus II (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>One of the following four subjects:</td>
<td></td>
</tr>
<tr>
<td>3.021 Introduction to Modeling and Simulation, 12, REST; 18.03*</td>
<td>12</td>
</tr>
<tr>
<td>1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; Calculus I (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>6.01 Introduction to EECS I, 12, 1/2 LAB; Physics II (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>3.016 Mathematical Methods for Materials Scientists and Engineers, 12; Calculus II (GIR)</td>
<td>12</td>
</tr>
<tr>
<td>3.022 Microstructural Evolution in Materials, 12; 3.012</td>
<td>12</td>
</tr>
<tr>
<td>3.024 Electronic, Optical, and Magnetic Properties of Materials, 12; 3.012</td>
<td>12</td>
</tr>
<tr>
<td>3.052 Mechanical Behavior of Materials, 12; Physics I (GIR), 3.016*</td>
<td>12</td>
</tr>
<tr>
<td>3.084 Organic and Biomaterials Chemistry, 12; 3.012</td>
<td>12</td>
</tr>
<tr>
<td>3.042 Materials Project Laboratory, 12, CI-M; 3.014*</td>
<td>12</td>
</tr>
<tr>
<td>3.044 Materials Processing, 12; 3.012, 3.022</td>
<td>12</td>
</tr>
<tr>
<td>3.TU Thesis, 9 **</td>
<td>12</td>
</tr>
<tr>
<td>3.93 Industrial Practice, 6</td>
<td>12</td>
</tr>
<tr>
<td>3.931 Industrial Practice, 6</td>
<td>12</td>
</tr>
</tbody>
</table>

**Notes:**

- **(1)** Plus 2 subjects designated as Communication Intensive in the Major (CI-M).
- **(2)** Required for SB degree.
- **(3)** May be replaced by 3.016 or 3.046.
- **(4)** Restricted Electives are designated by an asterisk (*).
- **(5)** Required for SB degree.
- **(6)** Restricted Electives are designated by an asterisk (*).
- **(7)** Required for SB degree.
- **(8)** Restricted Electives are designated by an asterisk (*).
- **(9)** Required for SB degree.
- **(10)** Restricted Electives are designated by an asterisk (*).
- **(11)** Required for SB degree.
- **(12)** Restricted Electives are designated by an asterisk (*).
- **(13)** Required for SB degree.
The 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, 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 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 3.985 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, Professor Heather Lechtman, will ensure that the minor program forms a coherent group of subjects.

A general description of the minor program at MIT may be found under Undergraduate Education in Part 1.

Inquiries
Additional information regarding undergraduate programs may be obtained from Professor Caroline Ross, Room 13-4005, 617-258-0223, carross@mit.edu, or from the Academic Office, Room 6-107, 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.

Doctoral Degree
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 department’s doctoral programs are organized into four main academic fields: electronic, photonic, and magnetic materials; bio- and polymer materials; structural and environmental materials; and emerging, fundamental, and computational studies in materials science. The academic 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 field; 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
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 (can be satisfied by 3.014 or 12.119 in the Departmental Program)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement (can be satisfied by 3.012, 3.021 or 12.001 in the Departmental Program)</td>
<td>2</td>
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<tr>
<td>Science Requirement</td>
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<tr>
<td>Humanities, Arts, and Social Sciences Requirement (can be satisfied by 3.986, 3.987, 3.988, and 21A.100 in the Departmental Program)</td>
<td>8</td>
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</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td>17</td>
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</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>152–162</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.012 Fundamentals of Materials Science and Engineering, 15, REST; 18.03*</td>
<td></td>
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<tr>
<td>3.014 Materials Laboratory, 12,LAB, CI-M</td>
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<tr>
<td>One of the following three subjects:</td>
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<tr>
<td>3.016 Mathematical Methods for Materials Scientists and Engineers, 12; Calculus II (GIR)</td>
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<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GIR)</td>
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<tr>
<td>18.034 Differential Equations, 12, REST; Calculus II (GIR)</td>
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<tr>
<td>One of the following three subjects:</td>
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<tr>
<td>3.022 Introduction to Modeling and Simulation, 12, REST; 18.03*</td>
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<tr>
<td>1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; Calculus I (GIR)</td>
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<tr>
<td>6.01 Introduction to EECS 1, 1/2 LAB; Physics II (GIR)</td>
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<tr>
<td>3.022 Microstructural Evolution in Materials, 12; 3.012</td>
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<tr>
<td>3.032 Mechanical Behavior of Materials, 12; Physics I (GIR), 3.016*</td>
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<td>or</td>
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<td>3.044 Materials Processing, 12; 3.012, 3.022</td>
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<tr>
<td>3.ThU Thesis, 9*</td>
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<tr>
<td>3.985 Archaeological Science, 9, HASS; Chemistry (GIR)*</td>
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<tr>
<td>3.986 The Human Past: Introduction to Archaeology, 12, HASS-D</td>
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<tr>
<td>3.987 Human Origins and Evolution, 9, HASS</td>
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<tr>
<td>3.990 Seminar in Archaeological Method and Theory, 9; 3.986, 3.985, 21A.100</td>
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<tr>
<td>12.001 Introduction to Geology, 12, REST</td>
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<tr>
<td>12.110 Sedimentary Geology, 12; 12.001</td>
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<tr>
<td>or</td>
<td>12.119 Analytical Techniques for Studying Environmental and Geologic Samples, 12, LAB</td>
</tr>
<tr>
<td>21A.100 Introduction to Anthropology, 12, HASS-D</td>
<td></td>
</tr>
</tbody>
</table>

Restricted Electives
21–24

One subject from the following list:
3.07 Introduction to Ceramics, 12; 3.012
3.14 Physical Metallurgy, 12; 3.013, 3.012, 3.022
3.051 Materials for Biomedical Applications, 12; Chemistry (GIR), Biology (GIR), 3.012*, 5.60*
3.052 Nanomechanics of Materials and Biomaterials, 12; 3.012*

One subject from the following list:
3.982 The Ancient Andean World, 9, HASS
3.983 Ancient Mesaoamerican Civilization, 9, HASS
3.984 Materials in Ancient Societies: Metals, 12; permission of Instructor
3.988 Africa—Past and Present, 9, HASS

Departmental Program Units That Also Satisfy the GIRs 90

Unrestricted Electives 97
photonic devices, battery electrolytes, organic 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.

**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 described under 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 described under Graduate Education in Part 1. The thesis must be materials-related, and an internal departmental thesis reader is required if the thesis 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. MEng students are not eligible for research assistant support, and teaching assistant support for MEng students is rare.

The MEng program targets two categories of students: 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 duration of 12 months. In the fall, students take two overview subjects, 3.205 and 3.225, designed for the MEng program. These subjects distill to 24 units the essential features of the 54-unit doctoral core, providing coverage of the basics of thermodynamic, kinetics, and properties of materials. These subjects offer adequate preparation for most of the department’s ad-
Joint Program with the Technology and Policy Program

The Master of Science in Technology and Policy is an engineering research degree with a strong focus on the role of technology in policy analysis and formulation. The Technology and Policy Program (TPP) curriculum provides a solid grounding in technology and policy by combining advanced subjects in the student’s chosen technical field with courses in economics, politics, and law. Many students combine TPP’s curriculum with complementary subjects to obtain dual degrees in 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 Engineering Systems Division 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 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 Engineering Systems Division or visit http://tppserver.mit.edu/.

Inquiries

Additional information regarding graduate programs, admissions, and financial aid may be obtained by writing to the Academic Office, Room 6-107, 617-253-3302.

Faculty and Staff

Faculty and Teaching Staff

Edwin L. Thomas, PhD
Morris Cohen Professor of Materials Science and Engineering
Department Head

Professors

Samuel Miller Allen, PhD
POSCO Professor of Physical Metallurgy
Ronald George Ballinger, ScD
Professor of Materials Science and Engineering and Nuclear Science and Engineering
Angela Belcher, PhD
Germeshausen Professor of Materials Science and Engineering and Biological Engineering
W. Craig Carter, PhD
Eugene Bell Professor of Materials Science and Engineering
MacVicar Faculty Fellow
Gerbrand Ceder, PhD
Richard P. Simmons Professor of Materials Science and Engineering

Yet-Ming Chiang, ScD
Kyocera Professor of Ceramics

Michael John Cima, PhD
Sumitomo Electric Industries Professor of Engineering

Joel Phillip Clark, ScD
Professor of Materials Systems

Thomas Waddy Eagar, ScD
Professor of Materials Engineering and Materials Systems

Eugene A. Fitzgerald, PhD
Merton C. Flemings—SMA Professor of Materials Science and Engineering

Lorna Jane Gibson, PhD
Matoula S. Salapatas Professor of Materials Science and Engineering

Professor of Civil and Environmental Engineering and Mechanical Engineering

Linn Walker Hobbs, DPhil
Professor of Materials Science and Nuclear Science and Engineering

Dorothy Hosler, PhD
Professor of Archaeology and Ancient Technology

Klavs Flemming Jensen, PhD
Warren K. Lewis Professor of Chemical Engineering and Materials Science and Engineering Head, Department of Chemical Engineering

Lionel Cooper Kimerling, PhD
Thomas Lord Professor of Materials Science and Engineering

Director, Materials Processing Center

Heather Nan Lechman, MA
Professor of Archaeology and Ancient Technology

Director, Center for Materials Research in Archaeology and Ethnology

Anne M. Mayes, PhD
Toyota Professor of Materials Science and Engineering

MacVicar Faculty Fellow

Caroline Anne Ross, PhD
Toyota Professor of Materials Science

Michael Francis Rubner, PhD
TDK Professor of Materials Science and Engineering

Director, Center for Materials Science and Engineering

Donald Robert Sadoway, PhD
John F. Elliott Professor of Metallurgy

Subra Suresh, ScD
Ford Professor of Materials Science and Engineering

Professor of Mechanical Engineering

Dean of Engineering

Carl Vernette Thompson II, PhD
Stavros Salapatas Professor of Materials Science and Engineering

Harry Louis Tuller, EngScD
Professor of Ceramics and Electronic Materials Engineering

Director, Crystal Physics and Optical Electronics Laboratory

Bernhardt John Wuensch, PhD
Professor of Ceramics

Sidney Yip, PhD
Professor of Nuclear Science and Engineering and Materials Science and Engineering

Yoel Fink, PhD
Associate Professor of Materials Science

MacVicar Faculty Fellow

Yang Shao-Horn, PhD
Associate Professor of Mechanical Engineering and Materials Science and Engineering

Assistant Professors
Silvija Gradecak, PhD
Merton C. Flemings Career Development Assistant Professor of Materials Science and Engineering

Randolph E. Kirchain, Jr., PhD
Assistant Professor of Materials Science and Engineering and Engineering Systems

Francesco Stellacci, PhD
Finmeccanica Career Development Assistant Professor of Materials Science and Engineering

Krystyn Van Vliet, PhD
Thomas Lord Assistant Professor of Materials Science and Engineering

Senior Lecturers
Paul I. David, PhD
James Duane Livingston, PhD

Lecturers
Geetha Berera, PhD
Joseph M. Dhosi

Harry Vincent Merrick, PhD
Joseph Parse, PhD

Meri Treska, PhD

Technical Instructors
Sidney W. Carter

Michael J. Tarkanian

Yin-Lin Xie

Instructor
Peter Houk

Research Staff

Visiting Scientists
Marco Fornari
Arne Hessenbruch
Yuichiro Koizumi
Hayato Miyagawa
Hiroomi Shimomura
Prabhat K. Tripathy
Kris Van Hege
Conrad Kang Xu

Haipeng Zheng
Senior Research Associate
Robert Charles O’Handley

Research Associates
Xiaoman Duan
Ying Shirley Meng
Kristin A. Persson
Timo Thonhauser

Research Scientists
David Bono
Sidney W. Carter
Fernando Castano
Ming Dao
Jifa Qi
Alan Schwartzman

Sponsored Research Technical Staff
Donald Galler

Research Specialist
George LaBonte

Technical Assistants
Vesal Dini
Amy M. Winans

Postdoctoral Associates
Nicola Bonini
Fevzi C. Cebeci
Dandeniyage C. I. De Alwis
Robert E. Doe
Mirela A. Dragan
Cedric Dubois
Can K. Erdonmez
Georg Ernest Fantner
Christopher Carl Fischer
Debadutip Ghosh
Byung Chan Han
Celine Nathalie Hin
Ying Hu
Ji Hyun Jang
Mohammad Mukul Kabir
Hyun Suk Kim
Woo Soo Kim
Pinar Kurt
Jae-Hwang Lee
Wentao Li
Martin Maldovan
Timothy K. Mueller
Sahak Petrosyan
Ratchatee Techapiesancharoenkij

Postdoctoral Fellows
Monica A. Diez Silva
Donghyun Kim
Hyun Suk Kim
Young Gun Ko
Denis Kramer
Georgios Lykotrafitis
Chung Hee Nam
Marc D. Natter
David Naves Otero
Hong Zhang

Research Affiliates
Connie Cheng
Gerald F. Dionne
Richard J. Gyory
Hsiao-Ying Huang
Young-II Jang
Theodoulos Kattamis
Davide M. Marini
Douglas Matson
Richard Mlcak
George A. Rossetti
Chris Scott
Hao Wang
Jessada Wannasin
John Zhenyu Wen
Arum Yu

Professors Emeriti
Robert Weieter Balluffi, ScD
Professor of Physical Metallurgy, Emeritus
Merton C. Flemings, ScD
Toyota Professor of Materials Processing,
Emeritus
Harry Constantine Gatos, PhD
Professor of Molecular Engineering and
Electronic Materials, Emeritus
Ronald Michael Latanision, PhD
Professor of Materials Science and Engineering

Frederick Jerome McGarry, SM
Professor of Civil Engineering and Polymer
Engineering, Emeritus
Regis Marc Noel Pelloux, ScD
Professor of Materials Engineering, Emeritus
Robert Michael Rose, ScD
Professor of Materials Science and Engineering,
Emeritus
Director, Concourse Program
Kenneth Calvin Russell, PhD
Professor of Metallurgy and Nuclear
Engineering, Emeritus
John Bruce Vander Sande, PhD
Professor of Material Science, 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 impassion 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: Design, Manufacturing, and Product Development. 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 development is offered.

Area 3: Controls, 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. 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; thermo-electric 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; desalination and water purification; 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 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-OE degree in mechanical and ocean engineering. It also serves as the focus point of ocean-related research and education at MIT. Major current research activities include marine robotics and navigation of underwater vehicles and smart sensors for ocean mapping and exploration; biomimetics to extract new understandings for the development of novel ocean systems studying marine animals; the study of the mechanics and fluid mechanics of systems for ultradepth ocean 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; ocean acoustics for communication, detection, and mapping in the ocean; and adaptive sampling and multidisciplinary forecasting of the ocean behavior. The Bachelor of Science in Mechanical Engineering/Course 2

### 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>2</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>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:
1. 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
2. 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 (prerequisites in italics).

<table>
<thead>
<tr>
<th>Subject Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Departmental Core Subjects</td>
<td>150</td>
</tr>
<tr>
<td>2.001 Mechanics and Materials I, 12; REST; Physics I (GIR), Calculus II (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>2.002 Mechanics and Materials II, 12; 2.001, Chemistry (GIR)</td>
<td></td>
</tr>
<tr>
<td>2.003 Dynamics and Control I, 12; REST; Physics I (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>2.004 Dynamics and Control II, 12; 2.003J, Physics II (GIR)</td>
<td></td>
</tr>
<tr>
<td>2.005 Thermal-Fluids Engineering I, 12; REST; Physics II (GIR), Calculus II (GIR), 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>2.008 Design and Manufacturing II, 12, 1/2 LAB; 2.001; 2.005; 2.007 or 2.017</td>
<td></td>
</tr>
<tr>
<td>2.009 The Product Engineering Process, 12, CI-M; 2.001, 2.003J, 2.005; 2.670 or 2.008; senior standing or permission of instructor</td>
<td></td>
</tr>
<tr>
<td>2.670 Mechanical Engineering Tools, 6</td>
<td></td>
</tr>
<tr>
<td>2.671 Measurement and Instrumentation, 12, LAB, CI-M; 2.001, 2.003J, Physics II (GIR)</td>
<td></td>
</tr>
<tr>
<td>2.672 Project Laboratory, 6, 1/2 LAB; 2.001, 2.003J, 2.006, 2.671</td>
<td></td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>2.71U Undergraduate Thesis, 6</td>
<td></td>
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<tr>
<td>or</td>
<td></td>
</tr>
<tr>
<td>2.007 Design and Manufacturing I, 12; 2.001, 2.670</td>
<td></td>
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<tr>
<td>or</td>
<td></td>
</tr>
<tr>
<td>2.017 Design of Electromechanical Robotic Systems, 12, 1/2 LAB; 2.003J; 2.005 or 2.016; 2.671</td>
<td></td>
</tr>
<tr>
<td>Restricted Elective Subjects</td>
<td>24</td>
</tr>
<tr>
<td>Students are required to take two of the following elective subjects (substitutions by petition to the ME Undergraduate Office).</td>
<td></td>
</tr>
<tr>
<td>2.016 Hydrodynamics, 12; Physics II (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>2.017 Design of Electromechanical Robotic Systems, 12, 1/2 LAB; 2.003J; 2.005 or 2.016; 2.671</td>
<td></td>
</tr>
<tr>
<td>2.019 Design of Ocean Systems, 12, CI-M; 2.001; 2.003J; 2.005 or 2.016; senior standing or permission of instructor</td>
<td></td>
</tr>
<tr>
<td>2.086 Numerical Computation for Mechanical Engineers, 12; 2.001, 2.003J, 2.005</td>
<td></td>
</tr>
<tr>
<td>2.092 Computer Methods in Dynamics, 12; 2.001, 2.003J, 2.005</td>
<td></td>
</tr>
<tr>
<td>2.12 Introduction to Robotics, 12; 2.004</td>
<td></td>
</tr>
<tr>
<td>2.14 Analysis and Design of Feedback Control Systems, 12; 2.004</td>
<td></td>
</tr>
<tr>
<td>2.370 Molecular Mechanics, 12; 2.001; Chemistry (GIR)</td>
<td></td>
</tr>
<tr>
<td>2.51 Intermediate Heat and Mass Transfer, 12; 2.006*</td>
<td></td>
</tr>
<tr>
<td>2.60I Fundamentals of Advanced Energy Conversion, 12; 2.006*</td>
<td></td>
</tr>
<tr>
<td>2.71 Optics, 12; Physics II (GIR); 18.03; 2.004*</td>
<td></td>
</tr>
<tr>
<td>2.72 Elements of Mechanical Design, 12; 2.005, 2.007, 2.671</td>
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</tr>
<tr>
<td>2.793I Fields, Forces and Flows in Biological Systems, 12; 2.005, 6.021, 20.320, or permission of instructor</td>
<td></td>
</tr>
<tr>
<td>2.797 Molecular, Cellular, and Tissue Biomechanics, 12; 18.03 or 3.016; Biology (GIR); 2.370 or 2.772</td>
<td></td>
</tr>
<tr>
<td>2.813 Environmentally Benign Design and Manufacturing, 12; 2.008 or permission of instructor</td>
<td></td>
</tr>
<tr>
<td>2.96 Management in Engineering, 12</td>
<td></td>
</tr>
<tr>
<td>Departmental Program Units That Also Satisfy the GIRs</td>
<td>(36)</td>
</tr>
<tr>
<td>Unrestricted Electives(2)</td>
<td>48</td>
</tr>
<tr>
<td>Total Units Beyond the GIRs Required for SB Degree</td>
<td>186</td>
</tr>
</tbody>
</table>

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.
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; fluids, 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 nanoeengineering 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 project-based laboratory and design experiences. All strive to develop independence, creative talent, and leadership, as well as the capability for continuing professional growth.

**Bachelor of Science in Mechanical Engineering/Course 2**

The program in mechanical engineering provides a broad intellectual foundation in the field of mechanical engineering. The program develops the relevant engineering fundamentals, includes various experiences in their application, and introduces the important methods and techniques of engineering practice.

The educational objectives of the program leading to the degree Bachelor of Science in Mechanical Engineering are that: (1) in their careers, graduates will bring to bear a solid foundation in basic mathematical and scientific knowledge and a firm understanding of the fundamental principles and disciplines of mechanical engineering; (2) graduates will use proper engineering principles when they model, measure, analyze, and design mechanical and thermal components and systems; (3) graduates
### Bachelor of Science in Engineering as recommended by the Department of Mechanical Engineering/Course 2-A

#### 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</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><strong>17</strong></td>
</tr>
</tbody>
</table>

#### 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

<table>
<thead>
<tr>
<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></td>
</tr>
</tbody>
</table>

#### Required Departmental Core Subjects

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.003 Mechanics and Materials I, 12, REST; Physics I (GIR), Calculus II (GIR), 18.03</td>
<td>78</td>
</tr>
<tr>
<td>2.005 Dynamics and Control I, 12, REST; Physics I (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>2.006 Thermal-Fluids Engineering I, 12, REST; Physics II (GIR), Calculus II (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>2.099 The Product Engineering Process, 12, CI-M; 2.001, 2.003J, 2.005; 2.670 or 2.008; senior standing or permission of instructor</td>
<td></td>
</tr>
<tr>
<td>2.670 Mechanical Engineering Tools, 6</td>
<td></td>
</tr>
<tr>
<td>2.671 Measurement and Instrumentation, 12, LAB, CI-M; 2.001, 2.003J, Physics II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GIR)</td>
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</tr>
</tbody>
</table>

#### Two Additional Mechanical Engineering Subjects

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.002 Mechanics and Materials II, 12; 2.003, Chemistry (GIR)</td>
<td>24</td>
</tr>
<tr>
<td>2.004 Dynamics and Control II, 12; 2.003J, Physics II (GIR)</td>
<td></td>
</tr>
<tr>
<td>2.005 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; 2.001; 2.005; 2.007 or 2.017</td>
<td></td>
</tr>
<tr>
<td>2.086 Numerical Computation for Mechanical Engineers, 12; 2.001, 2.003J, 2.005</td>
<td></td>
</tr>
<tr>
<td>2.08U Undergraduate Thesis, 12</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>72</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

- Alternate prerequisites and corequisites are listed in the subject description.
- These electives define a concentrated area of study and must be chosen with the written approval of the ME Undergraduate Office. A minimum of 66 units of engineering topics must be included in the 72 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., management subjects for an engineering management concentration). In all cases, the relationship of concentration subjects to the theme of the concentration must be obvious. A thesis (2.08U) of up to 12 units may be included among the concentration subjects if not already applied to the second-level 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 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 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 degree Bachelor of Science in Engineering as recommended by the Department of Mechanical Engineering.

This curriculum has been accredited by the Accreditation Board for Engineering and Technology as an engineering degree. (See accreditation discussion under the School of Engineering.)

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The educational objectives of the program leading to the degree of Bachelor of Science in Engineering as recommended by the Department of Mechanical Engineering are that: (1) in their careers, graduates will bring to bear a solid foundation in basic mathematical and scientific knowledge and a firm understanding of the basic principles and disciplines of
mechanical engineering; (2) graduates will use proper engineering principles when they model, measure, analyze, and design engineering systems, processes, and components; (3) graduates will have the professional skills necessary for formulating and executing design projects, for teamwork, and for effective communication; (4) graduates will demonstrate the confidence, awareness of societal context, professional ethics, and motivation for lifelong learning that are necessary for them to be leaders in their chosen fields of endeavor; and (5) graduates will 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; sustainable development; 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 and on the departmental website.

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 content (144 units) appropriate to the student’s field of study. The required core and second-level subjects include approximately 78 units of engineering topics. The self-designed concentration must include at least 66 more units of engineering topics. While engineering concentration must include at least 66 more 78 units of engineering topics. The self-designed and second-level subjects include approximately 144 units appropriate to a total of at least one and one-half years of study. 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 and on the departmental website.

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 content (144 units) appropriate to the student’s field of study. The required core and second-level subjects include approximately 78 units of engineering topics. The self-designed concentration must include at least 66 more units of engineering topics. While engineering topics are usually covered through engineering subjects, subjects outside the School of Engineering may provide material essential to the engineering program of some concentrations. For example, management subjects usually form an essential part of an engineering management concentration. In all cases, the relationship of

### 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>6</td>
<td>8</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>17</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication Requirement</th>
<th>Units</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>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLUS Departmental Program</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject names below are followed by credit units, and by prerequisites, if any (corequisites in italics).</td>
<td>150</td>
</tr>
<tr>
<td><strong>Required Departmental Subjects</strong></td>
<td></td>
</tr>
<tr>
<td>2.001 Mechanics and Materials I, 12; REST; Physics I (GIR), Calculus II (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>2.003 Dynamics and Control I, 12; REST; Physics I (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>2.004 Dynamics and Control II, 12; 2.003J, Physics II (GIR)</td>
<td></td>
</tr>
<tr>
<td>2.005 Thermal-Fluids Engineering I, 12; REST; Physics II (GIR), Calculus II (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>2.008 Design and Manufacturing II, 12; 3/2 LAB; 2.001; 2.003; 2.005; 2.007 or 2.009</td>
<td></td>
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<tr>
<td>2.012 Mechanics of Structures, 12; 2.001 or 1.050</td>
<td></td>
</tr>
<tr>
<td>2.016 Hydrodynamics, 12; 2.001 (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>2.017 Design of Electromechanical Robotic Systems, 12; 1.0 LAB; 2.003; 2.016 or 2.005; 2.671</td>
<td></td>
</tr>
<tr>
<td>2.019 Design of Ocean Systems, 12; CI-M; 2.001; 2.003J; 2.005 or 2.006; senior standing or permission of instructor</td>
<td></td>
</tr>
<tr>
<td>2.612 Marine Power and Propulsion, 12; 2.005</td>
<td></td>
</tr>
<tr>
<td>2.670 Mechanical Engineering Tools, 6</td>
<td></td>
</tr>
<tr>
<td>2.671 Measurement and Instrumentation, 12; LAB, CI-M; 2.001, 2.003J, Physics II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.03 Differential Equations, 12; REST; Calculus II (GIR)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Restricted Elective Subjects</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students are required to take two of the following elective subjects (substitutions by petition to the ME Undergraduate Office):</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>2.005 Acoustics and Sensing, 12; 2.003J, 6.003, 8.05, or 16.03</td>
<td></td>
</tr>
<tr>
<td>2.008j Structural Mechanics, 12; 2.002 or 2.012</td>
<td></td>
</tr>
<tr>
<td>2.086 Numerical Computation for Mechanical Engineers, 12; 2.001, 2.003J, 2.005</td>
<td></td>
</tr>
<tr>
<td>2.092 Computer Methods in Dynamics, 12; 2.001, 2.003J</td>
<td></td>
</tr>
<tr>
<td>2.112 Introduction to Robotics, 12; 2.004</td>
<td></td>
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<tr>
<td>2.14 Analysis and Design of Feedback Control Systems, 12; 2.004</td>
<td></td>
</tr>
<tr>
<td>2.20 Marine Hydrodynamics, 12; 2.006, 2.016, or 1.060</td>
<td></td>
</tr>
<tr>
<td>2.51 Intermediate Heat and Mass Transfer, 12; 2.006*</td>
<td></td>
</tr>
<tr>
<td>2.6d Fundamentals of Advanced Energy Conversion, 12; 2.006*</td>
<td></td>
</tr>
<tr>
<td>2.701 Principles of Naval Architecture, 12; 2.002 or 2.012</td>
<td></td>
</tr>
<tr>
<td>2.706 Sailing Vessel Design, 12; 2.701 or permission of Instructor</td>
<td></td>
</tr>
<tr>
<td>2.72 Elements of Mechanical Design, 12; 2.005, 2.007, 2.671</td>
<td></td>
</tr>
<tr>
<td>2.96 Management in Engineering, 12</td>
<td></td>
</tr>
<tr>
<td>2.97 Undergraduate Thesis, 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**

*Alternate prerequisites and corequisites 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.
concentration subjects to the particular theme of the concentration must be obvious.

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 intended for students who are interested in combining a firm foundation in mechanical engineering with a specialization in ocean engineering. The program includes engineering aspects of the ocean sciences, ocean exploration, and utilization of the oceans for transportation, defense, and extracting resources. Theory, experiment, and computation of ocean systems and flows are covered in a number of courses, complementing a rigorous mechanical engineering program; a hands-on capstone design class allows students to master the design of advanced marine systems, including autonomous underwater vehicles and smart sensors.

This curriculum has been accredited by the Accreditation Board for Engineering and Technology in both mechanical engineering and ocean engineering.

The educational objectives of the program leading to the degree Bachelor of Science in Mechanical and Ocean Engineering are that: (1) in their careers, graduates will bring to bear a solid foundation in basic mathematical and scientific knowledge and a firm understanding of the fundamental principles and disciplines of both mechanical and ocean engineering; (2) graduates will use proper engineering principles when they model, measure, analyze, and design mechanical, thermal, and ocean components and systems; (3) graduates will have the professional skills necessary for formulating and executing design projects, for teamwork, and for effective communication; and (4) graduates will demonstrate the confidence, awareness of societal context, professional ethics, and motivation for lifelong learning that are necessary for them to be leaders in their chosen fields of endeavor.

Graduates have exciting opportunities in the offshore and oceanographic industry, and the Navy or government, or for further study in graduate school.

**Undergraduate Practice Opportunities Program**

The Undergraduate Practice Opportunities Program, an innovative internship program administered and sponsored by the School of Engineering, offers opportunities to sophomores in the School. Further information on the program may be obtained from the department in which the student is registered or from Susann Luperfoy, executive director, Room 12-193, 617-253-0055, upop@mit.edu, or from 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 four of the ME program’s required core subjects.

**Inquiries**

Further information on undergraduate programs may be obtained from the Undergraduate Office, Room 1-110, 617-253-2305, me-undergradoffice@mit.edu, and from the downloadable Guide to the Undergraduate Program in Mechanical Engineering (http://web.mit.edu/me-ugoffice/gamed.pdf).

**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 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.

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, 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, or a minimum internet-based score of 91.

**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, not including thesis. Of these, at least 48 must be graduate H-level subjects (refer to the Guide to Graduate Study on the ME website). 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 three of the H-level subjects must be taken in mechanical engineering sciences (refer to the Guide to Graduate Study on the ME website). Students must take at least one graduate mathematics subject (12 units) offered by the MIT Mathematics Department. No waivers are allowed.

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 subsystems.

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 (refer to the Guide to Graduate Study on the ME website). Students must take at least one graduate mathematics subject (12 units) offered by MIT’s Mathematics Department. No waivers are allowed.

**Master of Engineering in Manufacturing**
The Master of Engineering in Manufacturing is a twelve-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/](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 under Engineering Systems Division in Part 2 or visit [http://lfm.mit.edu/](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 the doctoral qualifying examinations. 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, 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 under Interdisciplinary Graduate Programs in Part 2.

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
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, 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 under Interdisciplinary Research and Study in Part 1 and Interdisciplinary Graduate Programs in Part 2. 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.

**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.

**Design, Manufacturing, and Product Development**

**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.

Inquiries
For additional information, contact Leslie Regan, Mechanical Engineering Graduate Registration Office, Room 1-112, 617-253-2291, 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 (MMEC)

- Design, Manufacturing, and Product Development

- Controls, Instrumentation, and Robotics

- Energy Science and Engineering

- Ocean Science and Engineering

- Bioengineering

- Nano/Micro Science and Technology 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, 617-253-2291, me-gradoffice@mit.edu.
**Precision Systems Design and Manufacturing**
Modeling, design, and manufacturing methods for nanopositioning equipment, carbon nanotube-based mechanisms and machines, and compliant mechanisms.

**Controls, 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.

**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, and high heat fluxes; applied research in water purification, 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.

**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.

Faculty and Staff

Faculty and Teaching Staff
Mary C. Boyce, PhD
Gail E. Kendall Professor of Mechanical Engineering
MacVicar Faculty Fellow
Department Head

Professors
Rohan Abeyaratne, PhD
Quentin Berg Professor of Mechanics
MacVicar Faculty Fellow

Triantaphyllos R. Akyias, PhD
Professor of Mechanical Engineering

Lallit Anand, PhD
Professor of Mechanical Engineering

H. Harry Asada, PhD
Ford Professor of Engineering
Director, d’Arbeloff Laboratory for Information Systems and Technology

Arthur B. Baggeroer, ScD
Ford Professor of Engineering
Professor of Mechanical, Ocean, and Electrical Engineering

Klaus-Jürgen Bathe, PhD, DSc, Dr-Ing Eh, Dr hc Mult Professor of Mechanical Engineering
(On leave, spring)

John G. Brisson II, PhD
Professor of Mechanical Engineering
Gang Chen, PhD
Warren and Townley Rohsenow Professor of Mechanical Engineering
Wai K. Cheng, PhD
Professor of Mechanical Engineering
Chryssostomos Chryssostomidis, PhD
Henry L. and Grace Doherty Professor in Ocean Science and Engineering
Professor of Mechanical and Ocean Engineering
Director, MIT Sea Grant College Program

Jung-Hoon Chun, PhD
Professor of Mechanical Engineering
Director, Laboratory for Manufacturing and Productivity

Ernest G. Cravalho, PhD
Professor of Mechanical Engineering
MacVicar Faculty Fellow

Alex d’Arbeloff, SB
Professor of the Practice of Mechanical Engineering and Management

C. Forbes Dewey, Jr., PhD
Professor of Mechanical and Biological Engineering

Steven Dubowsky, ScD
Professor of Mechanical Engineering and Aeronautics and Astronautics

Ahmed F. Gholien, PhD
Ronald C. Crane Professor of Mechanical Engineering
Codirector, Center for 21st Century Energy

Lorna J. Gibson, PhD
Matoula S. Salapatas Professor of Materials Science and Engineering

Professor of Mechanical Engineering and Civil and Environmental Engineering

Leon R. Glicksman, PhD
Professor of Mechanical Engineering and Architecture

David C. Gossard, PhD
Professor of Mechanical Engineering

Stephen C. Graves, PhD
Abraham Siegel Professor of Management
Professor of Mechanical Engineering and Management

Linda G. Griffith, PhD
School of Engineering Professor of Teaching Innovation
Professor of Mechanical and Biological Engineering
Director, Biotechnology Process Engineering Center

Alan J. Grodzinsky, ScD
Professor of Mechanical, Electrical, and Biological Engineering

Timothy G. Gutowski, PhD
Professor of Mechanical Engineering

David E. Hardt, PhD
Ralph E. and Eloise F. Cross Professor of Mechanical Engineering
Professor of Engineering Systems

Douglas P. Hart, PhD
Professor of Mechanical Engineering

John B. Heywood, PhD, DSc, DTech (hon), DSc (hon)
Sun Jae Professor of Mechanical Engineering
Director, Sloan Automotive Laboratory
Director, MIT-Ford Alliance Program
Codirector, Center for 21st Century Energy

Neville J. Hogan, PhD, PhD (hon)
Professor of Mechanical Engineering and Brain and Cognitive Sciences
Director, Newman Laboratory

Ian W. Hunter, PhD
Hatsopoulos Professor of Mechanical Engineering
Director, Laboratory for Bioinstrumentation

Roger D. Kamm, PhD
Germeshausen Professor of Mechanical and Biological Engineering

(On leave, spring)

Mujid S. Kazimi, PhD
Professor of Mechanical and Nuclear Engineering

Robert S. Langer, PhD
Professor of Mechanical, Chemical and Biological Engineering
Institute Professor
Steven B. Leeb, PhD  
Professor of Mechanical and Electrical Engineering and Computer Science

John J. Leonard, PhD  
Professor of Mechanical and Ocean Engineering

John H. Lienhard V, PhD  
Professor of Mechanical Engineering  
Director, KFUPM Center for Clean Water and Clean Energy

Seth Lloyd, PhD  
Professor of Mechanical Engineering

Nicholas C. Makris, PhD  
Professor of Mechanical and Ocean Engineering

Henry S. Marcus, DBA  
Professor of Marine Systems

Gareth H. McKinley, PhD  
School of Engineering Professor of Teaching Innovation  
Professor of Mechanical Engineering  
Class of 1960 Fellow

Chiang C. Mei, PhD  
Ford Professor of Engineering  
Professor of Mechanical and Civil Engineering

Borivoje B. Mikic, ScD  
Professor of Mechanical Engineering

Jerome H. Milgram, PhD  
Professor of Mechanical and Ocean Engineering

David M. Parks, PhD  
Professor of Mechanical Engineering  
(On leave, fall)

Anthony T. Patera, PhD  
Ford Professor of Engineering

Nicholas M. Patrikalakis, PhD  
Kawasaki Professor of Engineering  
Professor of Mechanical and Ocean Engineering  
(On leave)

Derek Rowell, PhD  
Professor of Mechanical Engineering

Emanuel M. Sachs, PhD  
Fred Fort Flowers ’41 and Daniel Fort Flowers ’41  
Professor of Mechanical Engineering  
(On leave)

Henrik Schmidt, PhD  
Professor of Mechanical and Ocean Engineering

Paul D. Sclavounos, PhD  
Professor of Mechanical Engineering and Naval Architecture

Warren P. Seering, PhD  
Weber-Shaughness Professor of Mechanical Engineering  
Professor of Engineering Systems  
(On leave)

Alexander H. Slocum, PhD  
Neil and Jane Pappalardo Professor of Mechanical Engineering  
MacVicar Faculty Fellow

Jean-Jacques E. Slotine, PhD  
Professor of Mechanical Engineering and Brain and Cognitive Sciences

Joseph L. Smith, Jr., ScD  
Professor of Mechanical Engineering

Peter T. C. So, PhD  
Professor of Mechanical and Biological Engineering

Subra Suresh, ScD  
Ford Professor of Engineering  
Professor of Mechanical Engineering, Biological Engineering, and Materials Science and Engineering  
Dean of Engineering

Michael S. Triantafyllou, ScD  
W. I. Koch Professor of Marine Technology  
Professor of Mechanical and Ocean Engineering

David L. Trumper, PhD  
Professor of Mechanical Engineering

John Kim Vandiver, PhD  
Professor of Mechanical and Ocean Engineering  
MacVicar Faculty Fellow  
Director, Edgerton Center  
Dean for Undergraduate Research

Charles M. Vest, Ph.D  
President Emeritus  
(On leave)

David Wallace, PhD  
Professor of Mechanical Engineering and Engineering Systems  
MacVicar Faculty Fellow

Mark S. Welsh, NE  
Professor of the Practice of Naval Construction and Engineering

Tomasz Wierzbicki, ScD  
Professor of Applied Mechanics

James H. Williams, Jr., PhD  
School of Engineering Professor of Teaching Excellence  
Professor of Mechanical Engineering and Writing and Humanistic Studies  
(On leave, spring)

Gerald L. Wilson, ScD  
Vannevar Bush Professor of Electrical and Mechanical Engineering

Ioannis V. Yannas, PhD  
Professor of Mechanical Engineering, Polymer Science, and Biological Engineering

Camal Youcef-Toumi, ScD  
Professor of Mechanical Engineering

Dick Kau-Ping Yue, ScD  
Professor of Mechanical Engineering

Philip J. Solondz Professor of Engineering  
Professor of Mechanical and Ocean Engineering

Associate Professors

George Barbastathis, PhD  
Associate Professor of Mechanical Engineering

Martin Culpepper, PhD  
Associate Professor of Mechanical Engineering

Daniel Frey, PhD  
Associate Professor of Mechanical Engineering and Engineering Systems

Trent Gooding, NE  
Associate Professor of the Practice of Naval Construction and Engineering

Nicolas G. Hadjiconstantinou, PhD  
Associate Professor of Mechanical Engineering

Anette E. Hosoi, PhD  
Associate Professor of Mechanical Engineering

Joseph Jacobson, PhD  
Associate Professor of Mechanical Engineering and Media Arts and Sciences

Sang-Gook Kim, PhD  
Associate Professor of Mechanical Engineering  
(On leave, fall)
Matthew J. Lang, PhD
Associate Professor of Mechanical and Biological Engineering

Pierre F. J. Lermusiaux, PhD
Associate Professor of Mechanical and Ocean Engineering

Carol Livermore, PhD
Associate Professor of Mechanical Engineering

Scott Manalis, PhD
Associate Professor of Mechanical and Biological Engineering

Thomas Peacock, PhD
Associate Professor of Mechanical Engineering

Sanjay E. Sarma, PhD
Associate Professor of Mechanical Engineering

MacVicar Faculty Fellow

Yang Shao-Horn, PhD
Associate Professor of Mechanical Engineering

Alexandra H. Techet, PhD
Associate Professor of Mechanical and Ocean Engineering

Todd Thorsen, PhD
Associate Professor of Mechanical Engineering

(On leave, fall)

Assistant Professors

Tonio Buonassisi, PhD
SMA Assistant Professor of Mechanical Engineering and Manufacturing

Kimberly Hamad-Schifferli, PhD
Assistant Professor of Mechanical and Biological Engineering

Franz Hover, PhD
Doherty Career Development Assistant Professor in Ocean Utilization

Rohit N. Karnik, PhD
d’Arbeloff Assistant Professor of Mechanical Engineering

Evelyn N. Wang, PhD
Esther and Harold E. Edgerton Assistant Professor of Mechanical Engineering

Maria C. Yang, PhD
Robert N. Noyce Assistant Professor of Mechanical Engineering and Engineering Systems

(On leave, fall)

Senior Lecturers

John P. Appleton, PhD
Arthur Bergles, PhD
Ernesto E. Blanco, BME
David V. Burke, PhD
Stephen D. Fantone, PhD
Robert Hannemann, ScD
Edwin R. Hicks, PhD
Dean Kamen, PhD
Yuming Liu, PhD
Raymond, McCord, PhD
Hilario Oh, PhD
William Plummer, PhD
John Psarouthakis, PhD
Mark Schattenburg, PhD
Amy Smith, SM
Myron Spector, MD
Mandayam A. Srinivasan, PhD
Daniel E. Whitney, PhD

Lecturers

Alex Arzoumanidis, PhD
François Berthiaume, PhD
Harrison Chin, PhD
Wonjoon Cho, PhD
Matthew DuPlessie, PhD
Richard Fenner, BS
Jeffrey Fredberg, PhD
Julio Guerrero, PhD
W. Andrew Hodge, PhD
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Karl Iagnemma, PhD
Richard Kimball, PhD
Hauke Kite-Powell, PhD
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David Krebs, PhD
Serge La Fontaine, PhD
Richard Lee, MD
Guoan Li, PhD
Sheng Liu, PhD
Han Tong Loh, MS
Winston Maue, MS
James Preisig, PhD
Daniela Pucci de Farias, PhD
Neil Singer, PhD
Slobadan Tepic, PhD

Jeffrey Thomas, PhD/MD
Tian Tian, PhD
Shu Ben Tor, PhD
Douglas Vincent, PhD
Bruce Volpe
Victor Wong, PhD
Robert Wunderlick, MA
Boo-Hoo Yang, PhD
Dana R. Yoerger, PhD
Jerrold Zindler, MS

Instructor

Barbara Hughey, PhD

Technical Instructors

Joseph Cronin
David Dow
Pierce Hayward
Patrick McAtamney

Research Staff

Senior Research Engineers/Scientists

Anuradha Annaswamy, PhD
Stanley B. Gershwin, PhD
Mandayam A. Srinivasan, PhD

Principal Research Engineers/Scientists

James Bredt, PhD
Karl Iagnemma, PhD
Lynette A. Jones, PhD
H. Igo Krebs, PhD
Yuming Liu, PhD

Research Engineers/Scientists

Arjuna Balasuriya, PhD
Xiaoyuan Chen, MS
Wonjoon Cho, PhD
Joseph Curico, MS
John Folkesson, PhD
Patrick Haley, PhD
Kelli Hendrickson, PhD
Nora C. Hogan, PhD
Wayne Leslie, SM
Mark Schattenburg, PhD
Andrew Taberner, PhD
Postdoctoral Associates
Katia Bertoldi, PhD
Pradipto Bhattacharayya, PhD
Roland Bouffanais, PhD
Shuo Chen, PhD
Philipp Erni, PhD
Tomonori Honda, PhD
Genya Ishigami, PhD
Kenneth Kar, PhD
Gerardo Jose, PhD
Hyung Woo Lee, PhD
Yaning Li, PhD
Oleg Logutov, PhD
Renaud Rinaldi
Anindo Roy, PhD
Johannes Soulages, PhD
Cheng Hock Tan, PhD
Matthew Walter, PhD
Lifeng Wang, PhD
Guangyu Wu, PhD
Naoki Yabuuchi, PhD
Haidong Yuan, PhD
Cheng Zhang, PhD
Xuemei Zhu, PhD

Professors Emeriti
Ali S. Argon, ScD
Quentin Berg Professor of Mechanical Engineering, Emeritus
A. Douglas Carmichael, PhD
Professor of Mechanical and Power Engineering, Emeritus
Stephen H. Crandall, PhD
Ford Professor of Engineering, Emeritus
Ira Dyer, PhD
Professor of Mechanical and Ocean Engineering, Emeritus
James A. Fay, PhD
Professor of Mechanical Engineering, Emeritus
Woodie C. Flowers, PhD
Pappalardo Professor of Mechanical Engineering, Emeritus
Ernst G. Frankel, PhD, DBA
Professor of Mechanical Engineering and Marine Systems, Emeritus
Peter Griffith, ScD
Professor of Mechanical Engineering, Emeritus
Elias P. Gyftopoulos, ScD
Ford Professor of Engineering, Emeritus
James C. Keck, PhD
Professor of Mechanical Engineering, Emeritus
Justin E. Kerwin, PhD
Professor of Mechanical Engineering and Naval Architecture, Emeritus
Shih-Ying Lee, ScD
Professor of Mechanical Engineering, Emeritus
Richard H. Lyon, PhD, DrEng (hon)
Professor of Mechanical Engineering, Emeritus
Koichi Masubuchi, PhD
Kawasaki Professor of Engineering, Emeritus
Professor of Mechanical and Ocean Engineering and Materials Sciences and Engineering, Emeritus
Frank A. McClintock, PhD
Professor of Mechanical Engineering, Emeritus
J. Nicholas Newman, ScD
Professor of Mechanical Engineering and Naval Architecture, Emeritus
T. Francis Ogilvie, PhD
Professor of Mechanical and Ocean Engineering, Emeritus
Carl R. Peterson, ScD
Professor of Mechanical Engineering, Emeritus
Ronald F. Probst, PhD
Ford Professor of Engineering, Emeritus
Warren M. Rohsenow, DEng
Professor of Mechanical Engineering, Emeritus
Thomas B. Sheridan, ScD, D (hon)
Ford Professor of Engineering and Applied Psychology, Emeritus
Ain A. Sonin, PhD
Professor of Mechanical Engineering, Emeritus
Nam P. Suh, PhD, LHD (hon), EngD (hon), TekD (hon)
Ralph E. and Eloise F. Cross Professor of Mechanical Engineering, Emeritus
Neil E. Todreas, PhD
Professor of Nuclear and 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 peaceful applications of nuclear science and engineering. 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.

Applications fall within three main subcategories: nuclear energy, 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 societally important fields. Each of the three basic research areas involves substantial faculty and student activities. A synopsis of these activities follows.

**Nuclear Energy.** 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 need for new domestic supplies of electricity have led to a resurgence of interest in the design of advanced nuclear reactors. Nuclear reactors emit no greenhouse gases and therefore represent a highly attractive and realistic option for reducing the pollution that is causing global climate change.

The safe and economical development, design, construction, and operation of nuclear power plants and their related nuclear fuel recycling 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 policymakers 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 the continued development of low energy nuclear science and its application to fields such as medicine and biology, information processing, materials research, industrial processes, and radiation detection.

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 under way to apply this treatment to other types of cancer and to rheumatoid arthritis.

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 appli-
cable 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 quantum-enabled sensors and actuators, 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. 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 STUDY

Bachelor of Science in Nuclear Science and Engineering/Course 22

The Department of Nuclear Science and Engineering’s undergraduate program offers a strong foundation in science-based engineering, providing the skills and knowledge for a broad range of technical careers. The nuclear energy industry is experiencing a major resurgence worldwide, leading to high demand for nuclear engineers. Other nuclear and radiation applications are increasingly important in medicine, industry, and government. The program provides fundamental knowledge both in engineering, including thermodynamics and thermal-hydraulics, electronics, and computer methods, and in sciences—for example, electromagnetism, quantum mechanics, nuclear physics, and radiation technology.

Bachelor of Science in Nuclear Science and Engineering/Course 22

<table>
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<tr>
<th>General Institute Requirements (GIRs)</th>
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<tr>
<td>Science Requirement</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
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<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>can be satisfied from among 8.03, 18.03 or 18.034; 22.01; 22.02; and 22.071J, in the Departmental Program</td>
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<tr>
<td>Laboratory Requirement</td>
<td>can be satisfied by 22.09 in the Departmental Program</td>
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<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td></td>
<td>17</td>
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<table>
<thead>
<tr>
<th>Communication Requirement</th>
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<tbody>
<tr>
<td>The program includes a Communication Requirement of 4 subjects:</td>
<td></td>
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<tr>
<td>2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 subjects designated as Communication Intensive in the major (CI-M).</td>
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<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 (corequisites in italics)</td>
<td></td>
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<tr>
<td>Basic Requirements</td>
<td>84</td>
</tr>
<tr>
<td>2.005 Thermal-Fluids Engineering I, 12; REST; Physics II (GIR), Calculus II (GIR), 18.03</td>
<td></td>
</tr>
<tr>
<td>8.03 Physics III, 12; REST; Physics II (GIR), Calculus II (GIR), 12.010</td>
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<tr>
<td>18.03 Differential Equations, 12, REST; Calculus II (GIR) or 18.034</td>
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<tr>
<td>18.085 Computational Science and Engineering I, 12; Calculus II (GIR), 18.03</td>
<td>22.01 Introduction to Ionizing Radiation, 12, REST</td>
</tr>
<tr>
<td>Required Nuclear Science and Engineering Core Subjects</td>
<td></td>
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<tr>
<td>22.02 Introduction to Applied Nuclear Physics, 12, REST; Physics II (GIR), Calculus II (GIR)</td>
<td>22.055 Introduction to Applied Nuclear Physics, 12, REST; Calculus II (GIR), 18.03</td>
</tr>
<tr>
<td>22.033 Neutron Science and Reactor Physics, 12; 12.010; 18.03, 22.02</td>
<td>22.058 Principles of Tomographic Imaging, 12; Physics II (GIR), 18.03</td>
</tr>
<tr>
<td>Required Undergraduate Nuclear Science and Engineering Thesis</td>
<td></td>
</tr>
<tr>
<td>22.0ThT Undergraduate Thesis Tutorial (minimum of 3 units); 22.09</td>
<td>22.0ThU Undergraduate Thesis (minimum of 9 units), CI-M; 22.0ThU</td>
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<tr>
<td>Restricted Electives</td>
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<tr>
<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>2.791 Quantitative Physiology: Cells and Tissues, 12; Physics II (GIR), 18.03, 2.005*</td>
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<tr>
<td>Departmental Program Units That Also Satisfy the GIRs</td>
<td>(36)</td>
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<tr>
<td>Unrestricted Electives</td>
<td>48</td>
</tr>
<tr>
<td>Total Units Beyond the GIRs Required for SB Degree</td>
<td>192</td>
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</tbody>
</table>

No subject can be counted both as part of the 27-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 and corequisites 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.
tion generation and interactions. Building upon these fundamentals, students understand the principles, design, and appropriate application of nuclear systems—for example, reactors, imaging systems, detectors, and plasma confinement. In addition, they develop professional skills in quantitative research, written and oral technical communication, team building, and leadership. The program is excellent preparation for subsequent graduate education and research.

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 (22.07), 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, 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 for 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:

- 22.01 Introduction to Ionizing Radiation
- 22.02 Introduction to Applied Nuclear Physics
- 22.05 Neutron Science and Reactor Physics
- 22.06 Engineering of Nuclear Systems
- 22.058 Principles of Tomographic Imaging
- 22.09 Principles of Nuclear Radiation Measurement and Protection

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 undergraduate 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, 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.

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.

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 epithermal 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—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 Magnetic Resonance Laboratory, the full gamut of electron and 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 focus is on the engineering of quantum spin-based sensors, actuators, and 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 $^{10}$B(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 doctoral program receive financial aid for the duration of their education.

Application for financial aid should be made to Professor Sidney Yip, Room 24-102, 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, 617-253-3814, cengan@mit.edu.

FACULTY AND STAFF

Faculty and Teaching Staff

Ian Horner Hutchinson, PhD
Professor of Nuclear Science and Engineering
Department Head

Professors

George Apostolakis, PhD
KEPCO Professor of Nuclear Science and Engineering
Professor of Engineering Systems
Ronald George Ballinger, ScD
Professor of Nuclear Science and Engineering and Materials Science and Engineering
David Grant Cory, PhD
Professor of Nuclear Science and Engineering
Jeffrey Phillip Freidberg, PhD
KEPCO Professor of Nuclear Science and Engineering
Michael Warren Golay, PhD
Professor of Nuclear Science and Engineering
Linn Walker Hobbs, DPhil
Professor of Materials Science and Nuclear Science and Engineering
Andrew C. Kadak, PhD
Professor of the Practice, Nuclear Science and Engineering
Mujid Suliman Kazimi, PhD
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
Jacquelyn Ciel Yanch, PhD
Professor of Nuclear Science and Engineering
MacVicar Faculty Fellow
Sidney Yip, PhD
Professor of Nuclear Science and Engineering and Materials Science and Engineering
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 and 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 and Gender 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 China, France, Germany, Italy, Japan, Mexico, and Spain.

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 and Gender Studies Program
- Knight Science Journalism Fellows Program

See Interdisciplinary Research and Study in Part 1 for further information.
Publications
The Dean’s Office publishes the brochure School of Humanities, Arts, and Social Sciences@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.

Office of the Dean
Deborah K. Fitzgerald, PhD
Professor of the History of Technology
Kenan Sahin Dean
Kai von Fintel, PhD
Professor of Linguistics
Associate Dean
Marc B. Jones
Assistant Dean for Finance and Administration
Anne Marie Michel, MA
Assistant Dean for Development
Susan Mannett, BA
Director of Human Resources for SHASS
Bette K. Davis, EdD
Director, Humanities, Arts, and Social Sciences Education Office

Degrees Offered in the School of Humanities, Arts, and Social Sciences

<table>
<thead>
<tr>
<th>Course</th>
<th>Department</th>
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<tbody>
<tr>
<td>21A</td>
<td>Anthropology</td>
</tr>
<tr>
<td>21B</td>
<td>Anthropology</td>
</tr>
<tr>
<td>21F</td>
<td>Foreign Languages and Literatures</td>
</tr>
<tr>
<td>21H</td>
<td>History</td>
</tr>
<tr>
<td>21I</td>
<td>History</td>
</tr>
<tr>
<td>21L</td>
<td>Literature</td>
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<td>21M</td>
<td>Literature</td>
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<tr>
<td>17</td>
<td>Political Science</td>
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<td>14</td>
<td>Economics</td>
</tr>
<tr>
<td>24</td>
<td>Linguistics and Philosophy</td>
</tr>
<tr>
<td>23F</td>
<td>Program in Science, Technology, and Society</td>
</tr>
<tr>
<td>21W</td>
<td>Writing and Humanistic Studies</td>
</tr>
</tbody>
</table>

*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.
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 anthropological scholarship as well as perspectives on topics 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; science and technology; environmentalism; agriculture and food production; religion and symbolism; photography and film; ethics; law and human rights; gender studies; nationalism and ethnic identity; and the anthropology of medicine and scientific research. Geographical specializations include cultures of Africa, Latin America, the Caribbean, Asia, 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 include special topics and research subjects for undergraduates, and those ranging from 700 to 999 constitute advanced graduate subjects.

Students taking a concentration in anthropology should enroll in 21A.100 Introduction to Anthropology, and two other subjects. Anthropology subjects qualify for several interdisciplinary concentrations, including those in Women’s and Gender 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 and processes of meaning-making, 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 may 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 or 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 described 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**
Susan S. Silbey, PhD
Professor of Sociology and Anthropology
Section Head
(On leave, spring)

**Professors**
Michael M. J. Fischer, PhD
Professor of Anthropology and Science and Technology Studies
James Howe, PhD
Professor of Anthropology
Acting Section Head, spring
(On leave, fall)
Jean Elizabeth Jackson, PhD
Professor of Anthropology
MacVicar Faculty Fellow
(On leave, spring)

**Associate Professors**
Stefan Helmreich, PhD
Associate Professor of Anthropology
Heather A. Paxson, PhD
Associate Professor of Anthropology
(On leave, spring)
Christine J. Walley, PhD
Associate Professor of Anthropology
### Bachelor of Science in Anthropology/Course 21A

#### General Institute Requirements (GI-Rs)

<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 (three subjects may 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 GI-R 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

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>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 GI-Rs**

| (36) |

**Unrestricted Electives**

| 72–78 |

**Total Units Beyond the GI-Rs Required for SB Degree**

| 180 |

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

#### Notes

*Prerequisites and corequisites 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, CMS.100, one mid-tier subject, one capstone subject, and six electives. It is strongly recommended that students take a project-based subject that includes a substantial hands-on component as one of their electives. A pre-thesis tutorial (CMS.THT) and thesis (CMS.THU) may be substituted for one CMS elective. Students must obtain approval for their course selection from an advisor in their engineering or science field, and must also file a petition with the Subcommittee on the Communication Requirement.

Undergraduate subjects include:

- **Tier I**
  - 21L.011 The Film Experience
  - CMS.100 Introduction to Media Studies

- **Tier II (Mid-tier)**
  - CMS.400 Media Systems and Texts
  - CMS.405 Media and Methods: Performing
  - CMS.405 Media and Methods: Seeing and Expression

- **Tier III (Capstone)**
  - 21L.706 Studies in Film
  - 21L.715 Media in Cultural Context

- **Restricted Electives**
  - CMS.300 Introduction to Videogame Studies
  - CMS.309J/21W.763J Transmedia Storytelling: Modern Science Fiction
  - CMS.336J/21W.786J The Social Documentary
  - CMS.376 History of Media and Technology
  - CMS.590J/11.127J Computer Games and Simulations for Investigation and Education
  - CMS.600–CMS.604 Topics in Comparative Media Studies
  - CMS.607 The Role of the Gamer: Theory, Criticism, and Practice
  - CMS.608 Game Design
  - CMS.609J/21W.764J The Word Made Digital
  - CMS.610 Media Industries and Systems
  - 4.341 Introduction to Photography and Related Media
  - 4.351 Introduction to Video
  - 4.352 Advanced Video
  - 4.366 Advanced Projects in Visual Arts*
  - 4.602 Modern Art and Mass Culture
  - 17.243 Media Politics
  - 21A.336 Marketing, Microchips, and McDonalds: Debating Globalization
  - 21A.337 Documenting Culture
  - 21A.340J Technology and Culture
  - 21A.348 Photography and Truth
  - 21A.350J The Anthropology of Computing
  - 21A.360J The Anthropology of Sound
  - 21F.011 Topics in Indian Popular Culture
  - 21F.027J Visualizing Cultures
  - 21F.030 East Asian Culture: From Zen to Pop
  - 21F.035 Topics in Culture and Globalization
  - 21F.036 Advertising and Popular Culture: East Asian Perspectives
  - 21F.039 Japanese Popular Culture
  - 21F.052 French Film Classics
  - 21F.056 Visual Histories: German Cinema 1945 to Present
  - 21F.065 Japanese Literature and Cinema
  - 21F.067J Cultural Performances of Asia
  - 21F.341 Contemporary French Film and Social Issues
  - 21H.206 American Consumer Culture
  - 21H.223 War and American Society
  - 21H.546 World War II in Asia: Film, Fantasy, Fact
  - 21H.571J/CMS.882J Film, Fiction, and History in India, 1905–2005
  - 21L.421 Comedy
  - 21L.430 Popular Narrative*
  - 21L.432 Understanding Television
  - 21L.433 Film Styles and Genres
  - 21L.434 Science Fiction and Fantasy
  - 21L.435 Literature and Film

*When topic is applicable
Bachelor of Science in Comparative Media Studies/Course CMS

General Institute Requirements (GiRs)

<table>
<thead>
<tr>
<th>Subject</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>four subjects may be satisfied by subjects in the Departmental Program</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>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);
- 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>Tier I</td>
<td>48</td>
</tr>
<tr>
<td>CMS.100 Introduction to Media Studies, 12, HASS-D, CI-I</td>
<td></td>
</tr>
</tbody>
</table>

Tier II (Mid-tier)

Choose one of the following:
- CMS.400 Media Systems and Texts, 12, HASS, CI-M; one subject in CMS or permission of instructor
- CMS.400 Media and Methods: Performing, 12, HASS, CI-M; CMS.400, or permission of instructor
- CMS.405 Media and Methods: Seeing and Expression, 12, HASS, CI-M; CMS.400 or CMS.100

Tier III (Capstone)

Choose one of the following:
- 21L.016 Studies in Film, 12, HASS, CI-M; 21L.016 and one subject in CMS or Literature; or permission of instructor
- 21L.706 Media in Cultural Context, 12, HASS, CI-M; two subjects in CMS and/or Literature, or permission of instructor

Restricted Electives

Students choose six restricted electives; one should be a project-based subject or a subject with a substantial hands-on component. Qualified students may, with departmental approval, substitute a pre-thesis tutorial (CMS.ThT) and thesis (CMS.ThU) for one elective.

<table>
<thead>
<tr>
<th>Departmental Program Units That Also Satisfy the GiRs</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted Electives</td>
<td>(48)</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

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

Project-Based Subjects in Comparative Media Studies

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMS.590/11.127 Computer Games and Simulations for Investigation and Education</td>
<td></td>
</tr>
<tr>
<td>CMS.THT Pre-Thesis in Comparative Media</td>
<td></td>
</tr>
<tr>
<td>CMS.THU Undergraduate Thesis in Comparative Media</td>
<td></td>
</tr>
<tr>
<td>CMS.UR/URG Research in Comparative Media Studies</td>
<td></td>
</tr>
<tr>
<td>4.352 Advanced Video</td>
<td></td>
</tr>
<tr>
<td>4.366 Advanced Projects in Visual Arts*</td>
<td></td>
</tr>
<tr>
<td>21L.076 Studies in Film</td>
<td></td>
</tr>
<tr>
<td>21L.077 Problems in Cultural Interpretation*</td>
<td></td>
</tr>
<tr>
<td>21L.078 Literature and Technology</td>
<td></td>
</tr>
<tr>
<td>MAS.110 Fundamentals of Computational Media Design</td>
<td></td>
</tr>
<tr>
<td>MAS.849 Special Topics in Multimedia Production</td>
<td></td>
</tr>
</tbody>
</table>

*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.

CMS graduate students usually take three 12-unit subjects per term, plus a 3-unit colloquium. All students take three introductory seminars (Media Theories and Methods I and II, and Major Media Texts) during their first year, as well as two terms of Workshop, a subject that offers hands-on experience in media. In their final term they take a 24-unit subject devoted to completing the master’s thesis, plus the 3-unit Colloquium in Comparative Media. Typically, students will graduate with a total of 144 units; however a minimum of 139 units is required for the master’s degree in order to accommodate some electives that are 9-unit instead of 12-unit subjects.

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:

Required Subjects

- CMS.790 Media Theories and Methods I
- CMS.791 Media Theories and Methods II
- CMS.796 Major Media Texts
- CMS.801 Media in Transition
- CMS.950 Workshop I
- CMS.951 Workshop II
- CMS.980 Master’s Thesis
- CMS.990 Colloquium in Comparative Media

Electives

- CMS.710 Anthropology of Sound
- CMS.809 Transmedia Storytelling: Modern Science Fiction
- CMS.810 The Nature of Creativity
- CMS.820 Introduction to Philosophy of the Arts
- CMS.830 Studies in Film
- CMS.835 Photography and Truth
- CMS.836 The Social Documentary: Analysis and Production
- CMS.840 Literature and Film
- CMS.841 Introduction to Videogame Studies
- CMS.843 The Role of the Gamer: Theory, Criticism, and Practice
- CMS.845 Interactive and Non-linear Narrative: Theory and Practice
- CMS.846 The Word Made Digital
- CMS.863 Computer Games and Simulations for Investigation and Education
- CMS.864 Game Design
- CMS.871 Media in Cultural Context
- CMS.874 Visualizing Cultures
- CMS.876 History of Media and Technology
- CMS.882 Film, Fiction, and History in India, 1905–2005
- CMS.888 Advertising and Popular Culture: East Asian Perspectives
- CMS.910 Literature and Technology
- CMS.915 Understanding Television
- CMS.917 Documenting Culture
- CMS.920 Popular Narrative
- CMS.922 Media Industries and Systems
- CMS.925 Film Music
- CMS.935 Documentary Photography and Photojournalism: Still Images of a World in Motion
- CMS.992 Portfolio in Comparative Media
- CMS.993 Teaching in Comparative Media
- CMS.994 Topics in Comparative Media Studies
- CMS.995 Research in Comparative Media
- CMS.997–CMS.999 Topics in Comparative Media

Inquiries

For more information on the undergraduate and graduate programs in Comparative Media Studies, contact the CMS Office, Room 14N-207, 617-253-3599, fax 617-258-5133, cms@mit.edu.

FACULTY AND STAFF

Directors

- Henry Jenkins III, PhD
- Peter de Florez Professor of Humanities
- Professor of Comparative Media Studies
- William Uricchio, PhD
- Professor of Comparative Media Studies

Steering Committee*

- James Buzard, PhD
- 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

Faculty and Teaching Staff

Assistant Professors

- Beth Coleman, PhD
- Assistant Professor of Writing and New Media
- Nick Montfort, PhD
- Assistant Professor of Digital Media

Visiting Lecturers

- Glorianna Davenport, MA
- Jesper Juul, PhD
- Chris Weaver, MS

Research Staff

Research Managers

- Ellen Hume, BA
- Scot Osterweil, BA
- Erin Reilly, MFA
- Phillip Tan, MS

Postdoctorate Associates

- Joshua Green, PhD
- Doris Rusch, PhD

*The Comparative Media Studies program is jointly administered by three Humanities sections: Literature, Foreign Languages and Literatures, and Writing and Humanistic Studies. Approximately 30 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. 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, 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.

The department specifies one Restricted Electives 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:

<table>
<thead>
<tr>
<th>Tier I</th>
<th>Three subjects:</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.01</td>
<td>Principles of Microeconomics*</td>
</tr>
<tr>
<td>14.02</td>
<td>Principles of Macroeconomics*</td>
</tr>
<tr>
<td>and either</td>
<td></td>
</tr>
</tbody>
</table>

14.30 Introduction to Statistical Method in Economics  
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 elective undergraduate subjects chosen from the fields of applied economics. A list of specific subjects is available in the Economics Department Office, E52-391.

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 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 deficits.

Master of Science in Economics

Under special circumstances, admission may be granted to current MIT students seeking the Master of Science degree. The general requirements for the SM are given in the section on Graduate Education.

*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.
### Bachelor of Science in Economics/Course 14

<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></td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>2</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>
<th>Subjects</th>
<th>Units</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>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<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 (corequisites in italics).</td>
<td></td>
</tr>
<tr>
<td>Required Subjects</td>
<td>96–99</td>
</tr>
<tr>
<td>14.01 Principles of Microeconomics, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>14.02 Principles of Macroeconomics, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>14.04 Intermediate Microeconomic Theory, 12, HASS; 14.01, Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>14.05 Intermediate Applied Macroeconomics, 12, HASS, CI-M; 14.01, 14.02</td>
<td></td>
</tr>
<tr>
<td>14.30 Introduction to Statistical Method in Economics, 14.30, REST, Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>14.33 Econometrics, 12, 14.30</td>
<td></td>
</tr>
<tr>
<td>14.39 Research and Communication in Economics, 12, LAB, CI-M; 14.04, 14.05, 14.32</td>
<td></td>
</tr>
<tr>
<td>14.THU Thesis (15 units), 14.33(3)</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives</td>
<td>60</td>
</tr>
<tr>
<td>Elective subjects in economics</td>
<td></td>
</tr>
<tr>
<td>Departmental Program Units That Also Satisfy the GIRs</td>
<td>(60)</td>
</tr>
<tr>
<td>Unrestricted Electives</td>
<td>81–84</td>
</tr>
<tr>
<td>Total Units Beyond the GIRs Required for SB Degree</td>
<td>180</td>
</tr>
</tbody>
</table>

No subject can be counted 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 and corequisites are listed in the subject description.
- No more than three subjects in economics may be used for the Humanities, Arts, and Social Sciences Requirement.
- Or an approved alternative in statistics.
- 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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### 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 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 three 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. 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, 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 Peter Hoagland, Department of Economics, 617-253-8787, phoag@mit.edu.

### Faculty and Staff

**Faculty and Teaching Staff**

Ricardo J. Caballero, PhD  
Ford International Professor of Economics  
Department Head

Glenn D. Ellison, PhD  
Gregory K. Palm (1970) Professor of Economics  
Associate Head
Professors
K. Daron Acemoglu, PhD
Charles P. Kindleberger Professor of Economics
George-Marios Angeletos, PhD
Professor of Economics
Joshua Angrist, PhD
Ford Professor of Economics
David Autor, PhD
Professor of Economics
Abhijit Banerjee, PhD
Ford International Professor of Economics
Olivier Blanchard, PhD
Class of 1941 Professor of Economics
(On leave)
Victor Chernozhukov, PhD
Professor of Economics
Peter A. Diamond, PhD
Professor of Economics
Institute Professor
Esther Duflo, PhD
Abdul Latif Jameel Professor of Poverty
Alleviation and Development Economics
Amy Finkelstein, PhD
Professor of Economics
Robert S. Gibbons, PhD
Sloan Distinguished Professor of Management
and Economics
Michael Greenstone, PhD
3M Professor of Environmental Economics
Jonathan Gruber, PhD
Professor of Economics
MacVicar Faculty Fellow
Jeffrey E. Harris, MD, PhD
Professor of Economics
Jerry A. Hausman, DPhil
John and Jennie S. MacDonald Professor of Economics
Bengt R. Holmström, PhD
Paul A. Samuelson Professor of Economics
Paul L. Joskow, PhD
Elizabeth and James Killian Professor of Economics and Management
(On leave)
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
James M. Poterba, DPhil
Mitsui Professor of Economics
Drazen Prelec, PhD
Digital Equipment Corporation Leaders for Manufacturing Professor of Management
Professor of Economics and Brain and Cognitive Sciences
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
James Snyder, PhD
Arthur and Ruth Sloan 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
Robert Townsend, PhD
Elizabeth and James Killian Professor of Economics
Iván Werning, PhD
Professor of Economics
William C. Wheaton, PhD
Professor of Economics and Urban Studies
Director for Research, Center for Real Estate
Associate Professors
Mikhail Golosov, PhD
Rudi Dornbusch Career Development Associate Professor of Economics
Ben Olken, PhD
Associate Professor of Economics
Muhamet Yildiz, PhD
Associate Professor of Economics
Assistant Professors
Arnaud Costinot, PhD
Assistant Professor of Economics
Panle Jia, PhD
Assistant Professor of Economics
Guido Lorenzoni, PhD
Pentti J. K. Kouri Career Development Assistant Professor of Economics
Anna Mikusheva, PhD
Castle Krob Career Development Assistant Professor of Economics
Parag Pathak, PhD
Assistant Professor of Economics
Stephen P. Ryan, PhD
Silverman Family Career Development Assistant Professor of Economics
Senior Lecturer
Sara Fisher Ellison, PhD
Visiting Professors
James Anderson, PhD
Visiting Professor of Economics
Nick Bloom, PhD
Visiting Assistant Professor of Economics
Courtney Coile, PhD
Visiting Associate Professor of Economics
Lucas Davis, PhD
Visiting Associate Professor of Economics
Mathias Dewatripont, PhD
Visiting Professor of Economics
Peter Eso, PhD
Visiting Assistant Professor of Economics
Ernst Fehr, PhD
Visiting Professor of Economics
Francesco Giavazzi, PhD
Visiting Professor of Economics
Lorenz Goette, PhD
Visiting Associate Professor of Economics
Kiminori Matsuyama, PhD
Visiting Professor of Economics
Casey Rothschild, PhD
Visiting Assistant Professor of Economics
Robert Shimer, PhD
Visiting Professor of Economics

Jean Tirole, PhD
Visiting Professor of Economics

Robert Triest, PhD
Visiting Professor of Economics

Paul Willen, PhD
Visiting Associate Professor of Economics

Professors Emeriti
Morris A. Adelman, PhD
Professor of Economics, Emeritus

Robert L. Bishop, PhD
Professor of Economics, Emeritus

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
Professor of Economics, Emeritus

Paul A. Samuelson, PhD, LLD, DLitt, ScD
Professor of Economics, Emeritus
Gordon Y Billard Fellow
Institute Professor, Emeritus

Abraham J. Siegel, PhD
Howard W. Johnson Professor of Management, 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 languages. 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)

**Tier II**

Two language subjects at the advanced level:

- 21F.105 Chinese V (Regular)
- 21F.113 Chinese V (Streamlined)
- 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.

**Tier III**

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 21F.560, respectively, and include some assignments that require reading and writing in Chinese.

- 21F.030 East Asian Culture: From Zen to Pop
- 21F.036/21F.190 Advertising and Popular Culture: East Asian Perspectives
- 21F.038 The Cultural Politics of Contemporary China
- 21F.044 Traditional Chinese Literature
- 21F.045 Kung-Fu Cinema: Transnational Perspectives
- 21F.046/21F.192 Modern Chinese Fiction and Cinema
- 21H.504 East Asia in the World: 1500–2000 A.D.
- 21H.560/21F.191 Smashing the Iron Rice Bowl: Chinese East Asia
- 21H.580 From Silk Road to the Great Game: China, Russia, and Central Asia, 500–2000 A.D.

The **Minor Program in French** 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.303 French III
- 21F.304 French IV

**Tier II**

Two or three subjects from the following intermediate subjects in French language, literature, and culture: 21F.308–21F.315

**Tier III**

Two or three subjects from the following advanced subjects in French literature and culture: 21F.018, 21F.050, 21F.051, 21F.052, 21F.320–21F.348, 21H.346
The Minor Program in German consists of six subjects arranged into three levels of study as follows:

<table>
<thead>
<tr>
<th>Tier I</th>
<th>Two subjects or fewer depending on demonstrated level of entering competence:</th>
</tr>
</thead>
<tbody>
<tr>
<td>21F.403</td>
<td>German III</td>
</tr>
<tr>
<td>21F.404</td>
<td>German IV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tier II</th>
<th>Two subjects or three subjects from the intermediate subjects in German language, literature, and culture:</th>
</tr>
</thead>
<tbody>
<tr>
<td>21F.405</td>
<td>Germany Today: Intensive Study of German Language and Culture</td>
</tr>
<tr>
<td>21F.409</td>
<td>Opening the Text: Reading, Writing and Performing in German</td>
</tr>
<tr>
<td>21F.410</td>
<td>Professional Communication in German</td>
</tr>
<tr>
<td>21F.412</td>
<td>German Literature: An Introduction</td>
</tr>
</tbody>
</table>

| Tier III        | Two or three subjects from 21F.013, 21F.015, 21F.017, 21F.019, 21F.031, 21F.055, 21F.056, 21F.059, 21F.061, 21F.062, 21F.098, and 21F.414–21F.420 |

The Minor Program in Japanese consists of six subjects arranged into three levels of study as follows:

<table>
<thead>
<tr>
<th>Tier I</th>
<th>Two language subjects at the intermediate level:</th>
</tr>
</thead>
<tbody>
<tr>
<td>21F.503</td>
<td>Intermediate Japanese I</td>
</tr>
<tr>
<td>21F.504</td>
<td>Intermediate Japanese II</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tier II</th>
<th>Two language subjects at the advanced level:</th>
</tr>
</thead>
<tbody>
<tr>
<td>21F.505</td>
<td>Advanced Japanese I</td>
</tr>
<tr>
<td>21F.506</td>
<td>Advanced Japanese II</td>
</tr>
</tbody>
</table>

| 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.027, 21F.039, 21F.041, 21F.065, 21F.066, and 21F.067, respectively, and include some assignments |

**Notes**

* Alternate prerequisites and corequisites 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.
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.039/21F.591 Japanese Popular Culture
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.

FACULTY AND STAFF

Faculty and Teaching Staff
Isabelle de Courtivron, PhD
Professor of French Studies
MacVicar Faculty Fellow
Section Head

Professors
Elizabeth Garrels, PhD
Professor of French Studies
Shigeru Miyagawa, PhD
Kochi Prefecture-John Manjiro Professor of Japanese Language and Culture
Professor of Linguistics
Edward Baron Turk, PhD
Professor of French Studies and Film
John E. Burchard Professor of Humanities
William Uricchio, PhD
Professor of Comparative Media Studies
Codirector, Comparative Media Studies Program
Jing Wang, PhD
S. C. Fang Professor of Chinese Language and Culture

Associate Professors
Ian Condry, PhD
Mitsui Career Development Associate Professor of Japanese Cultural Studies
Margery Resnick, PhD
Associate Professor of Hispanic Studies
Emma Teng, PhD
Associate Professor of Chinese Studies

Senior Lecturers
Ellen Crocker, MA
Senior Lecturer in German
Undergraduate Academic Officer
Jane Dunphy, MA
Senior Lecturer in English Language Studies
Gilberte Furstenberg, Agrégation
Senior Lecturer in French
Sabine Levet, MA
Senior Lecturer in French
Douglas Morgenstern, MA
Senior Lecturer in Spanish

Lecturers
Patricia Brennecke, MA
Lecturer in English Language Studies
Tong Chen, MA
Lecturer in Chinese
Cathy Culot, MA
Lecturer in French
Ricardo Gessa, MA
Lecturer in Spanish
Margarita Ribas Groeger, MA
Lecturer
Director, Spanish Language Studies
Dagmar Jaeger, PhD
Lecturer in German
A. C. Kemp, MA
Lecturer in English Language Studies
Ayumi Nagatomi, MA
Lecturer in Japanese
Yoshimi Nagaya, MA
Lecturer
Director, Japanese Language Studies
Johann Sadock, PhD
Lecturer in French
Ikue Shingu, MA
Lecturer in Japanese

Lissette Soto, MA
Lecturer in Spanish

Peter Weise, PhD
Lecturer in German

Jin Zhang, MA
Lecturer in Chinese

Research Staff

Principal Research Associate
Kurt Fendt, PhD
Director, HyperStudio

Professors Emeriti
Catherine Vakar Chvany, PhD
Professor of Russian Studies, Emerita

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. Supplementing these requirements within the history curriculum is the stipulation of three additional subjects in a second field of humanities, arts, and social sciences: anthropology, economics, political science, literature, foreign languages and literatures—fields that provide the perspectives of another discipline on the history of human thought and behavior. This program is intentionally flexible; the relatively large number of electives and unrestricted time allows for the design of a course of study that meets individual needs and interests.

### 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.

### 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 described in Part 3. Further information on subjects and programs may be obtained from the History Office, Room E51-285, 617-253-4965.

### Faculty and Staff

#### Faculty and Teaching Staff

Anne E. C. McCants, PhD  
Professor of History  
MacVicar Faculty Fellow  
Section Head

**Professors**

John W. Dower, PhD  
Ford International Professor of History  
(On leave, fall)

Robert Michael Fogelson, PhD  
Professor of History and Urban Studies  
(On leave, spring)

Philip S. Khoury, PhD  
Ford International Professor of History  
Associate Provost

Pauline Maier, PhD  
William R. Kenan, Jr. Professor of History

Harriet Ritvo, PhD  
Arthur J. Conner Professor of History  
(On leave, spring)

Merritt Roe Smith, PhD  
Leverett and William Cutten Professor of the History of Technology

Craig Steven Wilder, PhD  
Professor of History

Elizabeth A. Wood, PhD  
Professor of History

#### Associate Professors

William Broadhead, PhD  
Associate Professor of History  
(On leave, spring)

Christopher Capozzola, PhD  
Lister Brothers Career Development Associate Professor of History

Meg Jacobs, PhD  
Associate Professor of History  
(On leave)

Jeffrey S. Ravel, PhD  
Associate Professor of History
Bachelor of Science in History/Course 21H

<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 (three subjects can 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>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td><strong>17</strong></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).

| Required Subjects | 57–60 |
| One 21H HASS-D subject (12 units) | |
| One 21H seminar subject (9–12 units) | |
| 21H.93 Seminar in Historical Methods, 12, CI-M, HASS * | |
| 21H.TH History Pre-Thesis Tutorial, 12 | |
| 21H.THU History Thesis, 12, CI-M * | |

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 | (27–33) |
| Unrestricted Electives | 48–72 |

Total Units Beyond the GIRs Required for SB Degree

| Notes |
| 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. |

*Prerequisites and corequisites 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 departure, 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.

**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 and Gender Studies

**Bachelor of Science in Humanities/Course 21**

<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 [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><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td><strong>17</strong></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>Restricted Electives</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>German</td>
<td>126–162</td>
</tr>
<tr>
<td>8 elective subjects in the field (which may include a pre-thesis and a thesis), plus a four-subject cluster (CI-M)</td>
<td></td>
</tr>
<tr>
<td>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, or 21F.416.</td>
<td></td>
</tr>
</tbody>
</table>

**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>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(27–36)</td>
</tr>
</tbody>
</table>

**Unrestricted Electives**

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>45–90</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**

- 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.
Bachelor of Science in Humanities and Engineering/21E, Bachelor of Science in Humanities and Science/21S

General Institute Requirements (GIrS)\(^4\)

<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 [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>
</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). 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 Department Program

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

Restricted Electives

For the humanities component, one of the following (further details may be obtained from the descriptions of programs in specific fields and the relevant field office):

- Anthropology
  - Nine subjects including 21A.100, 21A.110, and 21A.112. An honors thesis may be done at the invitation and approval of faculty. 102–108
- Foreign Languages and Literatures (in French, German, or Spanish)
  - Nine elective subjects, which may include a pre-thesis and thesis, subject to faculty approval. 81–102
- History
  - Seven elective subjects, a pre-thesis tutorial, and a thesis. 81–102
- Literature
  - Eight elective subjects (including two seminars and subjects in three historical periods or thematic complexes). 96
- Music
  - Eight 12-unit subjects, including 21M.220, 21M.301, 21M.302, 21M.300, one year (two 6-unit subjects) of performance, and three electives: one in Western or World music (21M.230–289 or 21M.291–299); one in theory/composition (21M.300–399), and one in history/literature, theory/composition, or performance (two 6-unit terms of 21M.401–499), to be selected in consultation with the major advisor. 96
- Writing: Creative or Expository
  - Seven subjects centered in creative or expository writing (one of these subjects is normally at the introductory level, one may be chosen from a related field), a pre-thesis tutorial, and a thesis. 96–102
- Writing: Science Writing or Technical Communication Studies
  - Four subjects in writing (including 21W.777, 21W.778, 21W.792, and a subject in basic exposition), three subjects from related curricula (including, for Science Journalism, subjects in the history and social context of science/technology, or, for Technical Communication, 9.00, a subject in graphics and design, and a subject in the structure of business organizations), a pre-thesis tutorial, and a thesis. 90–102
- American Studies\(^{11}\)
  - Seven elective subjects (including two in history and two in literature), a pre-thesis tutorial, and a thesis. Students may submit a request to the American Studies faculty advisor to substitute two classes in lieu of the pre-thesis and thesis. 81–102
- Ancient and Medieval Studies\(^{11}\)
  - Seven elective subjects (should follow the general structure of the Ancient and Medieval Studies Minor Program), a pre-thesis tutorial, and a thesis. 81–102
- Comparative Media Studies
  - Eight CMS subjects, including 21L.011 or CMS.100, one mid-tier subject (CMS.400, CMS.403, or CMS.405), one capstone subject (21L.706 or 21L.713), and five CMS electives. It is strongly recommended that students take a project-based subject that includes a substantial hands-on component as one of their CMS electives. A pre-thesis tutorial (CMS.Th1) and thesis (CMS.Thu) may be substituted for one CMS elective. 81–102
<table>
<thead>
<tr>
<th>Course Title</th>
<th>Units Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Asian Studies (1)</td>
<td>81–102</td>
</tr>
<tr>
<td>Latin American Studies (2)</td>
<td>81–102</td>
</tr>
<tr>
<td>Psychology (3)</td>
<td>81–102</td>
</tr>
<tr>
<td>Russian Studies (4)</td>
<td>81–102</td>
</tr>
<tr>
<td>Science, Technology, and Society (STS)</td>
<td>90–108</td>
</tr>
<tr>
<td>Theater Arts (5)</td>
<td>90–108</td>
</tr>
<tr>
<td>Women’s and Gender Studies (6)</td>
<td>81–102</td>
</tr>
</tbody>
</table>

**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. 54–72

**For 21S**
- Six elective subjects restricted to one of the science curricula and approved by a faculty member in the field. 54–72

**Departmental Program Units That Also Satisfy the GIRs**
- (54–72)

**Unrestricted Electives**
- 54–103

**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 on 21E and 21S**

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 and Gender Studies are also available as full majors by special arrangement with the Dean of the School of Humanities, Arts, and Social Sciences.

3. Russian language subjects are not offered at MIT, but may be taken at Harvard University or Wellesley College through cross-registration.

4. 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.

---

**Bachelor of Science in Philosophy/Course 24-1**

<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 (three subjects can be satisfied by subjects in the Departmental Program for the field of concentration)</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**

<table>
<thead>
<tr>
<th>Subject names below are followed by credit units and by prerequisites, if any (corequisites in italics).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required Subjects</strong></td>
</tr>
<tr>
<td>One HASS-D philosophy subject</td>
</tr>
<tr>
<td>One History of Philosophy subject</td>
</tr>
<tr>
<td>24.01 Classics in Western Philosophy, 12, HASS-D, CI-H</td>
</tr>
<tr>
<td>24.201 Topics in the History of Philosophy, 12, HASS, CI-M *</td>
</tr>
<tr>
<td>One Knowledge and Reality subject</td>
</tr>
<tr>
<td>24.09 Minds and Machines, 12, HASS-D, CI-H</td>
</tr>
<tr>
<td>24.111 Philosophy of Quantum Mechanics, 12, HASS</td>
</tr>
<tr>
<td>24.112 Space, Time, and Relativity, 12, HASS</td>
</tr>
<tr>
<td>24.114 A Philosophical History of Energy, 12, HASS</td>
</tr>
<tr>
<td>24.211 Theory of Knowledge, 12, HASS *</td>
</tr>
<tr>
<td>24.215 Topics in the Philosophy of Science, 12, HASS *</td>
</tr>
<tr>
<td>24.221 Metaphysics, 12, HASS *</td>
</tr>
<tr>
<td>24.251 Introduction to Philosophy of Language, 12, HASS *</td>
</tr>
<tr>
<td>24.253 Philosophy of Mathematics, 12, HASS *</td>
</tr>
<tr>
<td>24.280 Foundations of Probability, 12, HASS *</td>
</tr>
<tr>
<td>One Value subject</td>
</tr>
<tr>
<td>24.02 Moral Problems and the Good Life, 12, HASS-D, CI-H</td>
</tr>
<tr>
<td>24.04 Justice, 12, HASS-D, CI-H</td>
</tr>
<tr>
<td>24.06a Bioethics, 12, HASS-D, CI-H</td>
</tr>
<tr>
<td>24.12a Moral Psychology, 12, HASS, CI-M</td>
</tr>
<tr>
<td>24.209 Philosophy in Film and Other Media, 12, HASS</td>
</tr>
<tr>
<td>24.213 Philosophy of Film, 12, HASS</td>
</tr>
<tr>
<td>24.21a Introduction to Philosophy of the Arts, 12, HASS</td>
</tr>
<tr>
<td>24.222 Decisions, Games and Rational Choice, 12, HASS</td>
</tr>
<tr>
<td>24.231 Ethics, 12, HASS, CI-M</td>
</tr>
<tr>
<td>24.235j Philosophy of Law, 12, HASS *</td>
</tr>
<tr>
<td>24.235j Feminist Theory, 12, HASS, CI-M</td>
</tr>
<tr>
<td>24.263 The Nature of Creativity, 12, HASS, CI-M</td>
</tr>
<tr>
<td>One Logic subject</td>
</tr>
<tr>
<td>24.118 Paradox and Infinity, 12, HASS</td>
</tr>
<tr>
<td>24.241 Logic I, 12, HASS</td>
</tr>
<tr>
<td>24.242 Logic II, 12, HASS</td>
</tr>
<tr>
<td>24.243 Classical Set Theory, 12, HASS</td>
</tr>
<tr>
<td>24.244 Modal Logic, 12, HASS</td>
</tr>
<tr>
<td>and</td>
</tr>
<tr>
<td>24.260 Topics in Philosophy, 12, HASS, CI-M</td>
</tr>
</tbody>
</table>

**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 24.260 and one of the following: 24.120, 24.201, 24.231, 24.237, or 24.273.

**Departmental Program Units That Also Satisfy the GIRs**

| Unrestricted Electives | 84–99 |
Total Units Beyond the GIRs Required for SB Degree

No subject can be counted both as part of the 12-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 and corequisites are listed in the subject description.

1 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.

2 May not also satisfy the departmental distribution requirement in philosophy.

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

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Note that students are prohibited from majoring in both 24-1 and 24-2.

**Minor Programs**

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:

**Tier I**

*Two subjects:*

- Any HASS-D philosophy subject and
- 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)

**Tier II**

*Three non-introductory philosophy subjects, approved by the minor advisor*

**Tier III**

*One subject:*

24.260 Topics in Philosophy

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:

**Tier I**

*One subject:*

24.900 Introduction to Linguistics

**Tier II**

*At least three of the following, which must include 24.901, 24.902, and 24.903:*

- 24.901 Language and Its Structure I: Phonology
- 24.902 Language and Its Structure II: Syntax
- 24.903 Language and Its Structure III: Semantics and Pragmatics
- 24.904J Language Acquisition
- 24.905J Psycholinguistics

**Tier III**

*At least one term of:*

24.910 Topics in Linguistic Theory (can be repeated for credit)

---

**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, visit the website at [http://web.mit.edu/linguistics/www/mitili/](http://web.mit.edu/linguistics/www/mitili/) or contact the program administrator at 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. 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
- 24.959 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
- 24.995 Topics in Syntax
- 24.996 Topics in Phonology
- 24.997 Topics in Semantics
Bachelor of Science in Linguistics and Philosophy/Course 24-2

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRs)</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
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<td>Humanities, Arts, and Social Sciences Requirement (three subjects can be satisfied by subjects in the Departmental Program for the field of concentration)</td>
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</tr>
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<td>Restricted Electives in Science and Technology (REST) Requirement</td>
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<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
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>24.09 Minds and Machines, 12, HASS-D, CI-H</td>
<td>48</td>
</tr>
<tr>
<td>24.26 Logic I, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>24.25 Introduction to Philosophy of Language, 12, HASS *</td>
<td></td>
</tr>
<tr>
<td>24.00 Introduction to Linguistics, 12, HASS-D, CI-H</td>
<td></td>
</tr>
</tbody>
</table>

Students choose either a linguistics or philosophy track

Required Subjects for Linguistics Track

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.201 Language and Its Structure I: Phonology, 12, HASS *</td>
<td>48</td>
</tr>
<tr>
<td>24.001 Language and Its Structure II: Syntax, 12, HASS, CI-M *</td>
<td></td>
</tr>
<tr>
<td>24.002 Language and Its Structure III: Semantics and Pragmatics, 12, HASS *</td>
<td></td>
</tr>
<tr>
<td>24.010 Topics in Linguistic Theory, 12, HASS; CI-M *</td>
<td></td>
</tr>
</tbody>
</table>

Required Subjects for Philosophy Track

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.201 Topics in the History of Philosophy, 12, HASS, CI-M *</td>
<td>48</td>
</tr>
<tr>
<td>24.260 Topics in Philosophy, 12, HASS, CI-M *</td>
<td></td>
</tr>
</tbody>
</table>

One of the following Knowledge and Reality subjects:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.111 Philosophy of Quantum Mechanics, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>24.112 Space, Time, and Relativity, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>24.114J A Philosophical History of Energy, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>24.115 Theory of Knowledge, 12, HASS *</td>
<td></td>
</tr>
<tr>
<td>24.116 Topics in the Philosophy of Science, 12, HASS *</td>
<td></td>
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<tr>
<td>24.221 Metaphysics, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>24.253 Philosophy of Mathematics, 12, HASS *</td>
<td></td>
</tr>
<tr>
<td>24.280 Foundations of Probability, 12, HASS *</td>
<td></td>
</tr>
</tbody>
</table>

One of the following three subjects:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.64 Cognitive Processes, 12, HASS *</td>
<td></td>
</tr>
<tr>
<td>24.904 Language Acquisition, 12, HASS *</td>
<td></td>
</tr>
<tr>
<td>24.903 Psycholinguistics, 12, HASS *</td>
<td></td>
</tr>
</tbody>
</table>

Restricted Electives for Both Tracks

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>A coherent program of three additional subjects from one or two of the following three areas:</td>
<td>27–36</td>
</tr>
<tr>
<td>brain and cognitive sciences, linguistics, and philosophy.</td>
<td></td>
</tr>
</tbody>
</table>

Departmental Program Units That Also Satisfy the GIRs (36)

Unrestricted Electives

Total Units Beyond the GIRs Required for SB Degree

Notes

*Prerequisites and corequisites 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.

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 limited to these and probes into the candidate’s competence in linguistics in general.

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 course-work, 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, 617-253-9372.

FACULTY AND STAFF

Faculty and Teaching Staff Irene Heim, PhD Professor of Linguistics Department Head

Professors
Alexander Byrne, PhD Professor of Philosophy
Noam Chomsky, PhD Professor of Linguistics
Kai von Fintel, PhD Professor of Linguistics
Associate Dean, School of Humanities, Arts, and Social Sciences
Suzanne Flynn, PhD Professor of Second Language Acquisition
Daniel Fox, PhD Professor of Linguistics (On leave)
Edward A. Gibson, PhD Professor of Cognitive Science
Sally Haslanger, PhD Professor of Philosophy
Richard Holton, PhD Professor of Philosophy
Sabine Iatridou, PhD Professor of Linguistics

Michael Kenstowicz, PhD Professor of Linguistics (On leave)
Rae Langton, PhD Professor of Philosophy
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

Norvin Richards, PhD Professor of Linguistics
Irving Singer, PhD Professor of Philosophy
Robert Stalnaker, PhD Laurence S. Rockefeller Professor of Philosophy (On leave)

Donca Steriade, PhD Class of 1941 Professor of Linguistics
Kenneth N. Wexler, PhD Professor of Psychology and Linguistics
Stephen Yablo, PhD Professor of Philosophy

Associate Professors
Adam Albright, PhD Associate Professor of Linguistics
Michel DeGraff, PhD Associate Professor of Linguistics
Edward Flemming, PhD Associate Professor of Linguistics
Caspar Hare, PhD Associate Professor of Philosophy (On leave, fall)

Agustín Rayo, PhD Associate Professor of Philosophy
Roger White, PhD Associate Professor of Philosophy

Assistant Professor
Bradford Skow, PhD Assistant Professor of Philosophy

Professors Emeriti
Sylvain Bromberger, PhD Professor of Philosophy, Emeritus
Richard Lee Cartwright, PhD Professor of Philosophy, Emeritus
Morris Halle, PhD Institute Professor, Emeritus
James Wesley Harris, PhD Professor of Spanish and Linguistics, Emeritus
Samuel Jay Keyser, PhD Professor of Linguistics, Emeritus
Judith Jarvis Thomson, PhD Professor of Philosophy, Emeritus

Assistant Professor
Bradford Skow, PhD Assistant Professor of Philosophy

Professors Emeriti
Sylvain Bromberger, PhD Professor of Philosophy, Emeritus
Richard Lee Cartwright, PhD Professor of Philosophy, Emeritus
Morris Halle, PhD Institute Professor, Emeritus
James Wesley Harris, PhD Professor of Spanish and Linguistics, Emeritus
Samuel Jay Keyser, PhD Professor of Linguistics, Emeritus
Judith Jarvis Thomson, PhD Professor of Philosophy, Emeritus
The Literature Section’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 but remains 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 transferable 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; most introductory subjects carry HASS-Distribution credit, and all 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.
- **Seminar subjects** (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, popular culture, and 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:

<table>
<thead>
<tr>
<th>Tier</th>
<th>Level</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier I</td>
<td>Introductory Level</td>
<td>At least one and no more than two subjects from 21L.000–21L.017</td>
</tr>
<tr>
<td>Tier II</td>
<td>Intermediate Level</td>
<td>Two or three subjects from 21L.420–21L.512; Note: two samplings subjects (21L.310–21L.325) may be substituted for an intermediate level subject</td>
</tr>
<tr>
<td>Tier III</td>
<td>Seminar Level</td>
<td>At least two subjects from 21L.701–21L.715</td>
</tr>
</tbody>
</table>

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 described 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

Diana Henderson, PhD  
Professor of Literature

#### Professor

Diana Henderson, PhD
Bachelor of Science in Literature/Course 21L

General Institute Requirements (GIRs)

<table>
<thead>
<tr>
<th>Subjects</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>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>Units</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Subjects</td>
<td>36</td>
</tr>
<tr>
<td>Three seminar level subjects</td>
<td></td>
</tr>
</tbody>
</table>

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.473J, 21L.701, 21L.702, 21L.703, 21L.704, 21L.705, 21L.706, 21L.707, 21L.708, 21L.709.

Note: Four of the 10 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).

63–84

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.

Notes
For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
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 any student is welcome to audition for one or more of them. Auditions are held at the beginning of each term. Academic credit is available for some performance groups and private study.

Twenty-three professors and lecturers who specialize in composition, performance, music theory, and music history offer a wide variety of classes, which form our Music Program.

Bachelor of Science in Music/Course 21M

The undergraduate program leading to the degree of Bachelor of Science in Music is concerned with a confluence of three basic areas: a thorough grounding in the harmony and counterpoint of Western music; in-depth studies in the history and repertoire of Western and World music; and performing experience in small and/or large ensembles. Six required subjects (one of which consists of two terms of performance) and four electives (which must include subjects from three different areas) form the core of the program, which can be supplemented by eight unrestricted electives (for 96 additional units). This program is analogous to that for music majors at leading liberal arts colleges and universities, and it prepares a student in many ways for graduate study in the field. Students who declare music as their major must ordinarily demonstrate proficiency in instrumental or vocal performance by participating in a performance subject and in harmony/counterpoint by obtaining a grade of B or better in 21M.301.

Minor Program in Music

The Minor Program in Music requires six subjects that will give students experience within the three main branches of musical activity: performance, composition, and history. The four subjects in Tiers I and II are at the introductory or intermediate level. Those in Tier III provide depth in one of the three branches.

Tier I  
One subject, typically chosen from the following:
21M.011 Introduction to Western Music
21M.030 Introduction to World Music
21M.051 Fundamentals of Music

Students with sufficient musical knowledge or experience may substitute a subject from Tier II or III for the subject in Tier I. Please discuss this possibility with 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 music, a joint major in the 21E or 21S degree program provides an opportunity to study both fields. The joint major requires four subjects (21M.220, 21M.301, 21M.302, and 21M.500), two terms of performance subjects, electives in two musical fields (usually composition and history), a 12-unit elective in any musical field (composition, history, or two terms of performance), and six elective subjects in an engineering or science curriculum.

NB: Joint as well as full majors may, with faculty approval, substitute three full years of Advanced Musical Performance (21M.480) and a senior recital for the two required terms of performance subjects and two electives.

Students wishing to enroll in any of these degree programs should consult the major advisor in music no later than the first term of their junior year.

Subjects in music are described in Part 3. Further information on subjects and programs may be obtained from the Music Section Office, Room 4-246, 617-253-3210.

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.616 Learning from the Past: Performance, Drama, Science
21M.617 Science and Theatrical Imagination
21M.621 Theater and Cultural Diversity in the US
21M.710 Script Analysis
21M.711 Production Seminar
Bachelor of Science in Music/Course 21M

21M.712 African-American Performance
21M.713 Selected Studies in Theater

Tier II  Four subjects from the following:
21M.600 Introduction to Acting
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.670J Traditions in American Concert Dance: Gender and Autobiography
21M.675 Dance Theory and Composition
21M.703I Media and Methods: Performing (New)
21M.704 Musical Theater Workshop
21M.705 The Actor and the Text
21M.714 Selected Topics in Theater Arts (minimum of 9 units)
21M.715 Theater Design and Technical Exploration
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)
or
21M.606 Introduction to Stagecraft

and either
21M.805 Theater Practicum
or
21M.880 Dance Production
or a minimum of 6 units from the following subjects:
21M.851 Special Topics in Drama
21M.863 Advanced Topics in Theater Arts
21M.873 IAP Theater Arts Topics

Required Subjects
- 21M.220 Early Music, 12, HASS, CI-M; 21M.011*
- 21M.301 Harmony and Counterpoint I, 12, HASS-D; 21M.051*
- 21M.302 Harmony and Counterpoint II, 12, HASS; 21M.301
- 21M.303 Writing in Tonal Forms I, 12, HASS; 21M.302

Two terms of Performance subjects, 21M.401–21M.499 (6 units each)
21M.500 Senior Seminar in Music, 12, HASS, CI-M; 21M.302, two 21M.2xx subjects

Restricted Electives
- Four electives, consisting of one subject from each category below (12 units each):
  - Theory/composition (21M.300–21M.399)
  - Western music (21M.201–21M.289)
  - World music (21M.291–21M.299)

Choice of theory/composition, history/literature, or two terms of performance to be selected in consultation with the major advisor

Full majors may, with faculty approval, substitute three full years of 21M.480 Advanced Musical Performance and a senior recital for the two required terms of performance subjects and two of the four electives.

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
* Alternate prerequisites and corequisites 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.

Subjects in theater arts are described 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
Professor of Theater Arts

Peter Child, PhD
Professor of Music
MacVicar Faculty Fellow

Thomas F. DeFrantz, PhD
Class of 1948 Professor of Theater Arts

John Harbison, MFA
Professor of Music
Institute Professor

Ellen T. Harris, PhD
Class of 1949 Professor of Music

Lowell Edwin Lindgren, PhD
Professor of Music

Marcus Aurelius Thompson, DMA
Robert R. Taylor Professor of Music

Barry Lloyd Vercoe, DMA
Professor of Media Arts and Sciences

Evan Ziporyn, PhD
Kenan Sahin Distinguished Professor of Music

**Associate Professors**
Jay Scheib, MFA
Associate Professor of Theater Arts

Patricia J. Tang, PhD
Associate Professor of Music

**Assistant Professors**
Michael Cuthbert, PhD
Assistant Professor of Music
(On leave, fall)

Keeril Makan, PhD
Assistant Professor of Music
(On leave)

**Senior Lecturers**
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

Charles Shadle, PhD
Senior Lecturer in Music

Pamela Sharon Wood, MM
Senior Lecturer in Music

**Lecturers**
Adam Boyles, DMA
Lecturer in Music
Director, Orchestra

Sara Brown, MFA
Lecturer in Theater Arts

William C. Cutter, DMA
Lecturer in Music
Director, Choral Programs

Frederick Harris, PhD
Lecturer in Music
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

**Instructors**
Leslie Cocuzzo Held, BA
Technical Instructor in Theater Arts

Michael Katz, MFA
Technical Instructor in Theater Arts

Karen Perlow, BA
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)
- 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)
- 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 objective of the Minor Program in Political Science is to deepen and expand student knowledge of the discipline of political science. A minor in political science consists of six subjects divided into two tiers, selected from any of the discipline’s subfields as listed in Part 3. Tier I consists of introductory classes, and Tier II, of upper-level classes.

The requirements of the minor are as follows:

**Tier I**

- At least one but no more than two introductory classes (introductory classes are designated with two-digit numbers). These introductory classes provide broad theoretical and/or empirical overviews of their subject matter. Examples include:
  - 17.01J Justice
  - 17.20 Introduction to the American Political Process
  - 17.40 American Foreign Policy
  - 17.50 Introduction to Comparative Politics

**Tier II**

- At least four but no more than five upper-level classes (upper-level classes are designated with three-digit numbers). These specialized classes provide students with advanced and in-depth examination of their subject matter. Examples include:
  - 17.195 Globalization
  - 17.405 Politics and Conflict in the Middle East
  - 17.477J Technology and Policy of Weapons Systems
  - 17.811 Game Theory and Political Theory

For a listing of available subjects in these areas, consult Tobie Weiner in the Political Science Undergraduate Office, Room E53-484 or the HASS Education Office, Room 14N-410.

**Minor in Applied International Studies**

MIT students expect to be full participants in the global economy and research environment. The interdisciplinary HASS Minor in Applied International Studies prepares undergraduates for this reality by integrating international learning and experiences 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. The stay-abroad component is a requirement for completing the minor. Students select their options in close consultation with the minor advisor. The experience abroad will typically take place within an internship, research stay, service learning opportunity, or a study-abroad structure. Within this area, the minor offers students subjects that directly prepare them for these experiences before they go, and help them reflect on their work, research, or study-abroad experience after they return to campus. Students choose one or two subjects.

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.
The Department of Political Science offers degree programs at the bachelor’s, master’s, and doctoral levels.

**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 1 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 two semesters of intermediate-level college 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.

**Inquiries**

Additional information regarding graduate programs in the department and admissions may be obtained from the graduate administrator, Susan Twarog, 617-253-8336. Written inquiries should be addressed to Department of Political Science, Room E53-467.

**FACULTY AND STAFF**

**Faculty and Teaching Staff**

Charles Stewart III, PhD
Kenan Sahin Distinguished Professor
Professor of Political Science
Department Head

**Professors**

Stephen Ansolabehere, PhD
Elting E. Morison Professor of Political Science
(On leave)

Suzanne Berger, PhD
Raphael Dorman and Helen Starbuck Professor of Political Science

Nazli Choucri, PhD
Professor of Political Science

Richard M. Locke, PhD
Alvin J. Siteman Professor of Entrepreneurship and Political Science

Michael Joseph Piore, PhD
David W. Skinner Professor of Political Economy and Political Science
Barry R. Posen, PhD  
Ford Foundation International Professor of Political Science  
Director, Security Studies Program  

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  
Professor of Political Science  
(On leave, fall)  

**Assistant Professors**  
Fotini Christia, PhD  
Assistant Professor of Political Science  

Gabriel Lenz, PhD  
Assistant Professor of Political Science  

David Andrew Singer, PhD  
Assistant Professor of Political Science  
(On leave)  

**Professors Emeriti**  
Donald L. M. Blackmer, PhD  
Professor of Political Science, Emeritus  

Lincoln P. Bloomfield, PhD  
Professor of Political Science, Emeritus  

Joshua Cohen, 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  

**Associate Professors**  
Adam Berinsky, PhD  
Associate Professor of Political Science  
(On leave, fall)  

Andrea Campbell, PhD  
Associate Professor of Political Science  

Taylor Fravel, PhD  
Associate Professor of Political Science  
(On leave, fall)  

Orit Kedar, PhD  
Associate Professor of Political Science  
(On leave, fall)  

Chappell H. Lawson, PhD  
Associate Professor of Political Science  
(On leave, spring)  

Melissa Nobles, PhD  
Associate Professor of Political Science  

Kenneth A. Oye, PhD  
Associate Professor of Political Science  

Roger Petersen, PhD  
Associate Professor of Political Science  

Edward Steinfeld, PhD  
Associate Professor of Political Science  

Lily Tsai, PhD  
Associate Professor of Political Science  
(On leave, fall)  

**Associate Professor**  
Fotini Christia, PhD  
Assistant Professor of Political Science  

Gabriel Lenz, PhD  
Assistant Professor of Political Science  

David Andrew Singer, PhD  
Assistant Professor of Political Science  
(On leave)  

**Professors Emeriti**  
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Professor of Political Science, Emeritus  

Lincoln P. Bloomfield, PhD  
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Professor of Political Science, Emeritus  

**Assistant Professors**  
Fotini Christia, PhD  
Assistant Professor of Political Science  

Gabriel Lenz, PhD  
Assistant Professor of Political Science  

David Andrew Singer, PhD  
Assistant Professor of Political Science  
(On leave)  

**Professors Emeriti**  
Donald L. M. Blackmer, PhD  
Professor of Political Science, Emeritus  

Lincoln P. Bloomfield, PhD  
Professor of Political Science, Emeritus  

Joshua Cohen, PhD  
Professor of Political Science, Emeritus  

Willard R. Johnson, PhD  
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George W. Rathjens, PhD  
Professor of Political Science, Emeritus  

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Professor of Political Science, Emeritus  

Eugene B. Skolnikoff, PhD  
Professor of Political Science, Emeritus  

**Associate Professors**  
Adam Berinsky, PhD  
Associate Professor of Political Science  
(On leave, fall)  

Andrea Campbell, PhD  
Associate Professor of Political Science  

Taylor Fravel, PhD  
Associate Professor of Political Science  
(On leave, fall)  

Orit Kedar, PhD  
Associate Professor of Political Science  
(On leave, fall)  

Chappell H. Lawson, PhD  
Associate Professor of Political Science  
(On leave, spring)  

Melissa Nobles, PhD  
Associate Professor of Political Science  

Kenneth A. Oye, PhD  
Associate Professor of Political Science  

Roger Petersen, PhD  
Associate Professor of Political Science  

Edward Steinfeld, PhD  
Associate Professor of Political Science  

Lily Tsai, PhD  
Associate Professor of Political Science  
(On leave, fall)
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 Capstone Seminar in STS (STS.091 or STS.092). Prerequisite is completion of one STS HASS-D subject or permission of the STS undergraduate advisor.

**Double Major 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 double major 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 double major program must complete all the requirements of their majors as well as the STS requirements described below. They must also write a thesis in each field.

The STS requirements include 14 subjects as follows: one STS HASS-D subject; six other STS subjects; one Capstone seminar (STS.091 or STS.092); pre-thesis tutorial; the thesis; and four related HASS subjects forming a coherent group. Further details on the requirements of this double major may be obtained from the Department of Humanities and the STS undergraduate advisor.

**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 an interdisciplinary program in STS (STS.091 or STS.092) that 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; six other STS subjects; one STS Capstone seminar in STS (STS.091 or 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.210J, STS.250J, and STS.260J, in their first term. 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, visit the HASTS website at http://web.mit.edu/hasts/, or contact the STS academic administrator, Room E51-185, 617-253-9759.

Inquiries
Additional information on the Program in Science, Technology, and Society may be obtained from the STS academic administrator, Room E51-185, 617-253-9759, http://web.mit.edu/sts/.

For detailed descriptions of subjects in Science, Technology, and Society, see Part 3.

FACULTY AND STAFF

Faculty and Teaching Staff
David A. Mindell, PhD
Frances and David Dibner Professor of the History of Engineering and Manufacturing
Professor of Engineering Systems
Director

Michael M. J. Fischer, PhD
Andrew W. Mellon Professor in the Humanities

Deborah Fitzgerald, PhD
Professor of the History of Technology
Dean, School of Humanities, Arts, and Social Sciences

Kenneth Rogers Manning, PhD
Thomas Meloy Professor of Rhetoric and the History of Science

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 Social Studies of Science and Technology

Rosalind H. Williams, PhD
Bern Dibner Professor of the History of Science and Technology
**Associate Professors**
David S. Jones, PhD, MD  
Associate Professor of the History and Culture of Science and Technology  
David Kaiser, PhD  
Associate Professor of the History of Science  
Lecturer in Physics

**Assistant Professors**
Vincent Lépinay, PhD  
Assistant Professor of Science, Technology, and Society  
Clapperton Mavhunga, PhD  
Assistant Professor of Science, Technology, and Society  
Natasha Schüll, PhD  
Leo Marx Career Development Assistant  
Professor of Science, Technology, and Society  
Undergraduate Faculty Advisor  
Hanna Shell, PhD  
Assistant Professor of Science, Technology, and Society

**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 teaches students the craft, forms, and traditions of contemporary writing and communication. Some students explore writing as a means of artistic expression. Some learn how to communicate the results of their science and technical work to broad audiences and members of their professions. Others work collaboratively within the evolving framework of digital media to become skilled in interactive and nonlinear forms of communication. All subjects in the program emphasize the development of the foundational skills, creative initiative, and critical sensibility necessary to become a good writer.

Subjects in the program’s three options—creative writing (fiction, nonfiction prose, poetry), science writing, and digital media—are taught at both introductory and advanced levels. All subjects require extensive writing and revision. Student work is typically discussed in workshops and receives the written commentary of the instructor.

Concentrations in writing establish a course of study in fiction, prose nonfiction (including rhetoric), science writing, or digital media, and offer engineering or science majors an opportunity to develop abilities that will play a key role in their professional careers.

The Minor in Writing and Humanistic Studies offers students a sustained opportunity to work in one of the program’s three options while also exploring offerings in the program’s core curriculum.

The program also offers a one-year master’s degree (SM) in science writing. Students in the graduate program receive intensive training in the craft of turning technically complex ideas and discoveries into compelling writing and productions for broad audiences. Approaches in the graduate curriculum range from daily journalism to long-form prose, documentary audio and video, and digital media; students complete a required internship.

Bachelor of Science in Writing/Course 21W

The Program in Writing and Humanistic Studies offers three undergraduate options leading to the Bachelor of Science in Writing. The curriculum in creative writing is designed to develop expertise in writing and reading a genre of the student’s choice (e.g., fiction, poetry, or nonfiction prose forms), familiarity with related genres, and a three-subject focused exposure to an allied discipline, usually in the humanities, arts, or social sciences. This curriculum offers students flexibility in designing their courses of study for both breadth and depth.

The curriculum in science writing is designed to enable the student to develop mastery of the craft and rhetoric of writing about the worlds of science and engineering for broad audiences. This writing major is an option for students interested in science journalism, longer forms like the science documentary, and communication issues related to the public understanding of science and technology. It is also designed to work as a complementary major for students majoring in science, engineering, or another field of study at MIT. This major includes a three-subject exposure to an allied field such as science, technology, and society; political science; or comparative media studies. Students also fulfill an internship requirement, which provides in-depth practical experience.

The digital media major offers in-depth study of emerging interactive and nonlinear styles of narrative, as well as individual and collaborative experience in producing digitally mediated forms, both aesthetic and utilitarian. Students gain extensive experience in using a variety of authoring systems to develop large-scale websites, web-based hypertext products, computer games, interactive fiction and poetry, and digitally mediated visual worlds. Knowledge of programming is often helpful, but not necessary.

Minor Program in Writing

The Minor Program in Writing consists of six subjects focusing on one of the three areas mentioned above, arranged into two tiers of study as follows:

Tier I
- One subject from the following:
  - 21W.730 Writing on Contemporary Issues
  - 21W.731 Writing and Experience
  - 21W.732 Introduction to Scientific and 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 graduates 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 Writing Across the Curriculum Office 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.
Bachelor of Science in Writing/Course 21W

<table>
<thead>
<tr>
<th>General Institute Requirements (GIRe)</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 may 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 GIRe 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
Subject names below are followed by credit units, and by prerequisites, if any (corequisites in italics).

Option 1: Creative Writing (fiction, nonfiction, poetry)

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>21WThT Writing and Humanistic Studies Pre-Thesis Tutorial, 6</td>
<td></td>
</tr>
<tr>
<td>One of the following (CI-M): 21W.757, 21W.758, 21W.759, 21W.762, 21W.766L, 21W.770, 21W.771, or 21W.777</td>
<td></td>
</tr>
</tbody>
</table>

Restricted Electives
Seven subjects centered on creative writing, of which one is normally introductory; three subjects in literature, one of which may be in CMS.

Option 2: Science Writing

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>54</th>
</tr>
</thead>
<tbody>
<tr>
<td>21W.777 The Science Essay, 12, HASS, CI-M</td>
<td></td>
</tr>
<tr>
<td>21W.778 Science Journalism, 12, HASS, CI-H</td>
<td></td>
</tr>
<tr>
<td>21W.792 Science Writing Internship, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>21WThT Writing and Humanistic Studies Pre-Thesis Tutorial, 6</td>
<td></td>
</tr>
<tr>
<td>21WThU Writing and Humanistic Studies Thesis, 12, CI-M; 21W.ThT</td>
<td></td>
</tr>
</tbody>
</table>

Restricted Electives
Four subjects in writing, of which one is normally introductory; three are writing subjects approved for this major, one of which is in digital media (48 units).
One approved Science, Technology, and Society subject (12 units).

Option 3: Digital Media

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>54</th>
</tr>
</thead>
<tbody>
<tr>
<td>21W.764 The Word Made Digital, 12, HASS, CI-M</td>
<td></td>
</tr>
<tr>
<td>21W.765 Interactive and Non-Linear Narrative: Theory and Practice, 12, HASS</td>
<td></td>
</tr>
<tr>
<td>21W.785 Communicating with Web-based Media, 12, HASS, CI-H</td>
<td></td>
</tr>
<tr>
<td>21WThT Writing and Humanistic Studies Pre-Thesis Tutorial, 6</td>
<td></td>
</tr>
<tr>
<td>21WThU Writing and Humanistic Studies Thesis, 12, CI-M; 21W.ThT</td>
<td></td>
</tr>
</tbody>
</table>

Restricted Electives
Four subjects in writing, which may be in digital media, creative writing, or science writing, and three related subjects from any of the following courses: 6, 21L, MAS, STS; or CMS

Departmental Program Units That Also Satisfy the GIRe

| (27–36) |

Unrestricted Electives

| Option 1 | 42–72 |
| Option 2 | 66   |
| Option 3 | 42–63 |

Total Units Beyond the GIRe Required for SB Degree

180

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

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 described 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.

Faculty and Staff

Faculty and Teaching Staff
James Paradis, PhD
Robert M. Metcalfe Professor of Writing

Program Head

Professors
Robert Kanigel, BS
Professor of Science Writing

Thomas Levenson, BA
Professor of Science Writing

Kenneth R. Manning, PhD
Thomas Meloy Professor of Rhetoric and the History of Science

James H. Williams, Jr., PhD
SEPTE Professor of Engineering
Charles F. Hopewell Faculty Fellow

Rosalind H. Williams, PhD
Bern Dibner Professor of the History of Science and Technology

Associate Professors
Junot Díaz, MFA
Associate Professor of Writing

Helen Elaine Lee, JD
Associate Professor of Writing
**Assistant Professors**

Vivek Bald, PhD  
Assistant Professor of Writing and Digital Media  
Beth Coleman, PhD  
Assistant Professor of Writing and New Media  
Nick Montfort, PhD  
Assistant Professor of Digital Media

**Visiting Professors**

Marcia Bartusiak, MS  
Visiting Professor of Science Writing  
Thomas Glave, MFA  
Visiting Professor of Writing

**Adjunct Professors**

Joe Haldeman, MFA  
Adjunct Professor of Fiction  
Alan Lightman, PhD  
Adjunct Professor of the Humanities

**Senior Lecturer**

Edward Barrett, PhD  
Senior Lecturer in Writing

**Lecturers**

Cherie Abbanat, MA  
Atissa Banuazizi, MA  
Karen Boiko, PhD  
Harlan Breindel, MA  
Mary Caulfield, MA  
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  
Lisa Dush, MA  
Rebecca Faery, PhD  
Director, First Year Writing  
Erica Funkhouser, MA  
William Haas, PhD  
Philip J. Hilts  
Sarah King, PhD  
Neal Lerner, EdD  
Shariann Lewitt, MFA

Lucy Marx, MA  
Janis Melvold, PhD  
Benjamin Miller, PhD  
Marilee Ogren-Balkema, PhD  
Karen Pepper, PhD  
Mya Poe, PhD  
Director, Technical Communication  
Kym Ragusa, MFA  
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 41N-410, 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 departure within Course 21. Individual programs are to be determined in consultation with Professor William Broadhead, Room E51-175, 617-258-6668.

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 their work, research, or study abroad and helps them to reflect on these experiences after they 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 Serenella Sferza, minor advisor, Center for International Studies, E38-755, 617-452-2693, ssferza@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 socio-economic 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 Alan Hein, Room 46-2047, 617-253-2295, hein@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 Judith Layzer, Room 9-328, 617-253-5196, jlayzer@mit.edu, in Urban Studies and Planning.

Women's and Gender Studies Program

Women's and Gender 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 30 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 subjects in the field of Women's and Gender Studies 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 and Gender 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 and Gender Studies also offers a minor program and a concentration.

The Minor Program in Women's and Gender 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:

**Tier I**
- Required introductory subject:

**Tier II**
- *Four subjects, at least one of which is drawn from each category:*
  - Humanities and the arts
  - Social and natural sciences

**Tier III**
- **One advanced seminar:**
  - SP.412 Feminist Political Thought
  - an upper-level Women's and Gender Studies subject as determined by the director

For more information, see Interdisciplinary Research and Study in Part 1 or contact the coordinator, Heidy M. González, Women's and Gender Studies, Room 14E-316, 617-253-8844, wgs@mit.edu, or visit http://web.mit.edu/wgs/.

Graduate Consortium in Women's Studies

The Graduate Consortium in Women's Studies (GCWS) offers team-taught, interdisciplinary graduate seminars available to students from MIT and its eight other member institutions: Boston College, Boston University, Brandeis University, Harvard University, Northeastern University, Simmons College, Tufts University, and the University of Massachusetts Boston. Students from the nine member institutions learn together in interdisciplinary and cross-institutional class environments, investigating cutting-edge issues in Women’s and Gender Studies together with the teaching team.

The Consortium is currently administered at MIT. The seminars offer MIT graduate credit for students enrolled at the member institutions.

New seminars are developed on an ongoing basis; visit the GCWS website, http://web.mit.edu/gcws/, or email gcws@mit.edu for current class listings.

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-level 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-410, 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 and 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 Helen Elaine Lee, Room 14N-425, 617-253-3060, helee@mit.edu, or from the HASS Education Office, Room 14N-410, 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 Shigeru Miyagawa, Room 32-0886, 617-253-6346, miyagawa@mit.edu, or the HASS Education Office, Room 14N-410, 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 Isabelle de Courtivron, Room 14N-311, 617-253-4776, or from the HASS Education Office, Room 14N-410, 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 semester 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-323, 617-253-9688, egarrels@mit.edu, or from the HASS Education Office, Room 14N-410, 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 10-280, 617-253-0887, or from the HASS Education Office, Room 14N-410, 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-410, 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.

Sustainability Lab (S-Lab). Utilizing a collaborative, interdisciplinary approach to sustainability challenges, S-Lab is jointly taught by seven of the School’s top faculty and features opportunities to work with a variety of companies as they confront environmental and social business challenges.

China Lab. MIT Sloan’s partnership with four premier business schools in China was expanded to include an intensive, semester-long opportunity for students from both countries to learn and work together collaboratively. Involving 32 Chinese international MBA students and 24 MIT Sloan students, the inaugural China Lab incorporated elements of Project Team China and the popular E-Lab and G-Lab courses to give students hands-on work experience as part of a multinational business team.
Research Centers
MIT Sloan’s interdisciplinary research centers include:

- Center for Collective Intelligence
- Center for Computational Research in Economics and Management Science
- Center for Digital Business
- Center for Energy and Environmental Policy Research
- Institute for Work and Employment Research
- Laboratory for Financial Engineering
- Lean Advancement Initiative
- MIT Entrepreneurship Center
- Operations Research Center
- Productivity from Information Technology Initiative
- System Dynamics Group

Information about each of these is available in the Interdisciplinary Research and Study section in Part 1.

MIT Sloan is also home to other research centers and programs, such as the MIT Leadership Center, the MIT Workplace Center, and those described below.

The Center for Information Systems Research (CISR) was established in 1974 and has a strong record of accomplishment of practice-based research on the management and use of information technology (IT). The center’s mission is to perform practical empirical research on how firms generate business value from IT. An international mix of almost 40 sponsoring organizations, representing a broad range of industries, assist in defining and executing this research. Faculty and staff associated with the center have conducted pioneering research in such areas as decision support systems, critical success factors, database systems, strategic IS planning, management of the IT function, and the use of information by management, including executive support systems. CISR develops concepts models and provides insights into the role of IT in enabling new business strategies, management processes, and organizational structures. 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/.

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/.

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/.

Degrees Offered in the MIT Sloan School of Management

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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.

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/.

Office of the Dean
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General Motors Leaders for Manufacturing Professor of Management
Professor of Engineering Systems
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Deputy Dean
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Senior Associate Dean for Finance and Administration
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Senior Associate Dean
PART

MINOR PROGRAM IN MANAGEMENT

Minor Program in Management Science

The Minor Program in Management Science introduces undergraduates in other majors to the techniques of quantitative business analysis and their application to practical problems. Its focus reflects the core content of the SB degree program in management science.
The minor consists of six subjects, four required:

- 6.041 Proabilistic Systems Analysis
- 14.01 Principles of Microeconomics
- 15.053 Optimization Methods in Management Science
- 15.075 Statistical Thinking and Data Analysis

Plus
- Two Course 15 subjects selected from a list of restricted electives. (Two six-unit subjects will be counted as a single elective subject.)

**Minor Program in Management**

The Minor in Management provides undergraduates in other majors with an understanding of the economic, business, human, social, and organizational dimensions of scientific and technological enterprise. The minor consists of six subjects, four required:

- 14.01 Principles of Microeconomics
- 15.501 Corporate Financial Accounting
- 15.668 People and Organizations
- 15.812 Marketing Management

Plus
- Any two Course 15 subjects (other than UROP, Special Studies, Special Seminars, and general-elective transfer credit) that are not designated as restricted to students in other Sloan School programs. (Two six-unit subjects will be counted as a single elective subject.)

**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 course bidding system. Information about the process is available on the bidding website at [https://sloanbid.mit.edu/](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 on the bidding website, 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 course bidding system.

**Inquiries**
For additional information about these Sloan undergraduate programs, students may consult the Office of Undergraduate Programs, Room E52-117, 617-253-8614, and the MIT Sloan undergraduate website, [http://mitsloan.mit.edu/undergrad/](http://mitsloan.mit.edu/undergrad/).

**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 for the MBA and doctoral programs 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 term, 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.
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 Engineering Systems Division 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 full-time 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 MBA (or SM in management) 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 who are 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
- Economic Sociology
- Financial Economics
- Information Technologies
- Institute for Work and Employment Research
- Technological 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 known 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 may decide that further study of a foreign language is necessary if the student is to work effectively in his or her major field.

**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/](http://mitsloan.mit.edu/mba/); questions may be directed to mbaadmissions@sloan.mit.edu. For doctoral information, contact the Doctoral Program Office, Room E52-126, 617-253-8600, or contact the program office, Room E52-126, 617-253-8600, fax 617-252-1200, fellows@sloan.mit.edu.

**Faculty and Staff**

- David C. Schmittlein, PhD
- John C. Head III Dean
- Steven D. Eppinger, ScD
- General Motors Leaders for Manufacturing Professor of Management
- Professor of Engineering Systems
- Deputy Dean
- JoAnne Yates, PhD
- Sloan Distinguished Professor of Management
- Deputy Dean

**Faculty and Teaching Staff**

**Professors**

Deborah Gladstein Ancona, PhD

Paul Asquith, PhD

Gordon Y. Billard Professor of Finance

Arnold Irwin Barnett, PhD

George Eastman Professor of Management Science

Professor of Operations Research and Management

Ernst R. Berndt, PhD

Louis E. Seley Professor in Applied Economics

Dimitris Bertsimas, PhD

Boeing Leaders for Manufacturing Professor of Management

Codirector, Operations Research Center

Gabriel Richard Bitran, PhD

Society of Sloan Fellows Professor

Erik Brynjolfsson, PhD

George and Sandra Schussel Professor of Management Science

Codirector, MIT Center for Digital Business

John Stephen Carroll, PhD

Morris A. Adelman Professor of Management

John Carrington Cox, PhD

Nomura Professor of Finance

Michael A. Cusumano, PhD

Sloan Management Review Professor in Management

(On leave)

**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 offers 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 the website at [http://mitsloan.mit.edu/fellows/](http://mitsloan.mit.edu/fellows/) or contact the program office, Room E52-126, 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) program offers a master’s degree to students interested in the analysis and application of computational approaches to designing and operating engineered systems. The curriculum is designed with a common core serving all engineering disciplines and an elective component focusing on specific applications. Current MIT graduate students may pursue a CDO master’s degree in conjunction with a department-based master’s or PhD program. For more information, see the full program description under Interdisciplinary Graduate Programs or visit [http://web.mit.edu/cdo-program/index.html](http://web.mit.edu/cdo-program/index.html).
David Gamarnik, PhD
J. Spencer Standish (1945) Associate Professor of Management

Yasheng Huang, PhD
China Program Associate Professor of International Management

Leonid Kogan, PhD
Nippon Telegraph and Telephone Associate Professor of Management
(On leave)

David McAdams, PhD
Cecil and Ida Green Career Development Associate Professor

Fiona Elizabeth Murray, PhD
Sarofim Family Career Development Associate Professor

Jun Pan, PhD
Associate Professor of Finance

Georgia Perakis, PhD
Associate Professor of Management

Nelson Repenning, PhD
Associate Professor of Management

Roberto Rigobón, PhD
Associate Professor of Economics

Antoinette Schoar, PhD
Class of 1957 Career Development Assistant Professor

Michael Braun, PhD
Assistant Professor of Marketing

Emilio Castilla, PhD
W. Maurice Young (1963) Career Development Assistant Professor
(On leave)

Damon Centola, PhD
Assistant Professor of System Dynamics

Hui Chen, PhD
Assistant Professor of Finance

Jason Davis, PhD
Assistant Professor of Strategy

Joseph J. Doyle, PhD
Jon D. Gruber Career Development Assistant Professor in Finance

Vivek Farias, PhD
Assistant Professor of Operations Management

Carola Frydman, PhD
Assistant Professor of Finance

Michael Grubb, PhD
Assistant Professor of Finance

Richard Timothy Holden, PhD
Assistant Professor of Applied Economics
(On leave)

Scott Joslin, PhD
Assistant Professor of Economics, Finance, and Accounting

Kate Kellogg, PhD
Class of 1954 Career Development Assistant Professor
(On leave)

Mozaffar Khan, PhD
Assistant Professor of Accounting

Retsef Levi, PhD
Robert N. Noyce Career Development Assistant Professor

Denise Lewin Loyd, PhD
Sloan School Career Development Assistant Professor

Gustavo Manso, PhD
Assistant Professor of Finance
(On leave)

Mark Mortensen, PhD
Richard S. Leghorn (1939) Career Development Assistant Professor in Management of Technological Innovation

Jeffrey Ng, PhD
Assistant Professor of Accounting

Elena Obukhova, PhD
Assistant Professor of International Economics and Management

Sugata Roychowdhury, PhD
Theodore T. Miller (1922) Career Development Assistant Professor

Ewa Sletten, PhD
Assistant Professor of Accounting

Taveet Suri, PhD
Mitsubishi Career Development Assistant Professor in International Management

Catherine Tucker, PhD
Douglas Drane Career Development Assistant Professor in Information Technology and Management
(On leave)

Rodrigo Verdi, PhD
Assistant Professor of Accounting
(On leave)

Chris Wheat, PhD
Assistant Professor of Strategy

Pai-Ling Yin, PhD
Assistant Professor of Marketing

Adjunct Professor

Mary P. Rowe, PhD
Adjunct Professor of Management

Professor of the Practice

Alex d’Arbeloff, SB
Honorary Chairman of the MIT Corporation

Senior Lecturers

Noubar Afeyan, PhD
John Akula, PhD, JD
Seth Alexander, BS
Howard Anderson, MBA
Bill Porter (1967) Professor of Entrepreneurship
William Aulet, MS
Peter W. Bell, LLDD
Patricia Bentley, PhD
Lori Breslow, PhD
Stephen F. Brown, AB
John F. Carrier, DS
Phil Cooper, MS
Thomas Copeland, PhD
Michael Davies, MBA
A. Denny Ellerman, PhD
Jonathan Fleming, MPA
Cyrus Gibson, PhD
Jack Gill, PhD
Michael Grandinetti, MBA
Joseph G. Hadzima, Jr., JD
Leigh Hafrey, PhD
Neal Hartman, ABD
William Neal Isaacs, DPhil
Craig Jarchow, PhD
Charles F. Kane, MBA
Christine Kelly, PhD
Janice Klein, PhD
Mark Kritzman, MBA
David Kurtz, MBA
Peter Kurzina, JD
Shari Loesberg, JD
Jeffrey Alan Meldman, PhD, JD
Director, Undergraduate Programs
Associate Dean, Office of the Dean for Undergraduate Education
Kenneth P. Morse, MBA
Managing Director, MIT Entrepreneurship Center
John Parsons, PhD
Executive Director, MIT Center for Energy and Environmental Policy Research
John T. Preston, MBA
John M. Reilly, PhD
John Rockart, PhD
Donald Barry Rosenfield, PhD
Director, Leaders for Manufacturing Fellows Program
Anjali Sastry, PhD
Claus Otto Scharmer, PhD
Peter M. Senge, PhD
Jeffrey Shames, SM
Janet Shanberge, MS
E. Sarah Slaughter, PhD
Henry Birdseye Weil, SM
Andrew Wolk, MBA
Kenneth Zolet, SM

Lecturers
Kara Blackburn, MA
Catherine Calarco, MBA
Amy J. Mokady, MA
Jonathon David Pelly, MBA
Luis Perez-Breva, PhD
Roberta Pittore, MBA
Phil Primack, MPA
John Richardson, JD

Research Staff
Senior Research Scientist
Peter Weill, PhD
Chairman, Center for Information Systems Research

Principal Research Associates
Mark Klein, PhD
George Roth, PhD
Alexander Samarov, PhD

Principal Research Scientists
Jeanne Ross, PhD
Director, Center for Information Systems Research
Michael D. Siegel, PhD

Research Associates
Daniel Goldsmith, MBA
Robert Laubacher, MA

Research Scientists
Elaine Backman, BA
Nils Fonstad, PhD
Peter Gloor, PhD
Danica Mijovic-Prelac, PhD
George Westerman, PhD
Stephanie Woerner, PhD

Professors Emeriti
Thomas John Allen, Jr., PhD
Howard W. Johnson Professor of Management, Emeritus
Lotte Lazarsfeld Baily, PhD
T. Wilson Professor of Management, Emeritus

Jay W. Forrester, DEng
Germeshausen Professor of Management, Emeritus
Arnoldo Cubillos Hax, PhD
Alfred P. Sloan Professor of Management, Emeritus
Henry Donnan Jacoby, PhD
William F. Pounds Professor of Management, Emeritus
Codirector, Joint Program on the Science and Policy of Global Change
Howard Wesley Johnson, LLD
Speciality Faculty Professor of Management
Former Chairman, MIT Corporation
President, Emeritus
Gordon Mayer Kaufman, DBA
Morris A. Adelman Professor of Operations Research and Management, Emeritus
Robert Bruce McKersie, PhD
Professor of Management, Emeritus
Michael Stewart Scott Morton, DBA
Forrester Professor of Management, Emeritus
William F. Pounds, PhD
Professor of Management, Emeritus
Paul Samuelson, PhD
Institute Professor, Emeritus
Edgar H. Schein, PhD
Professor of Management, Emeritus
Abraham J. Siegel, PhD
Howard W. Johnson Professor of Management, Emeritus
Dean, Emeritus
D. Eleanor Westney, PhD
Society of Sloan Fellows Professor of International 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.
The School of Science is an amazing enterprise. With approximately 300 faculty members, 1200 graduate students, 1000 undergraduate majors and similarly large numbers of postdoctoral researchers and research staff, it is large enough to carry out research at the frontiers in every field of science. Our faculty members have won 16 Nobel Prizes and our alumni have won 16 Nobel prizes; most of these have come in the past 20 years. The six departments in the School are consistently rated among the best in the world.

Some members of our community study deep philosophical questions: What is the nature of Dark Matter and Dark Energy, which make up 95% of the content of our universe? How does our brain—a complex system of interconnected neurons, give rise to our mind—our consciousness and ability to learn?

Other faculty members study problems that have obvious practical implications: How does global warming increase the intensity of hurricanes? Can we make adult stem cells capable of generating any cells in the body, so that we could replace cells damaged by disease without using embryos?

Thus, the School is a magnificent generator of new knowledge. However, among the great research universities, MIT is unique in having a School of Science that is deeply committed to education. MIT provides each of its undergraduates with an understanding of the basic elements of biology, chemistry, mathematics and physics, and our Science faculty are devoted to doing this well. Some of our most famous faculty members, even a few with Nobel Prizes, are also some of the best teachers of our freshman subjects.

Our science majors are provided with the very best introduction to their chosen field, as well as the opportunity to participate in forefront research, so if they decide to pursue graduate studies, they are superbly prepared. On the other hand an education in science 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 our graduate students have pursued 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 make creative contributions to the modern world.

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.

Science Laboratories and Centers
To provide the facilities necessary for research and to encourage research groups to collaborate, much of our research in Science is carried out in large research laboratories and centers. Those, whose members are primarily from the School of Science are:

- Koch Institute for Integrative Cancer Research
- Laboratory for Nuclear Science
- McGovern Institute for Brain Research
- MIT Kavli Institute for Astrophysics and Space Research
- Picower Institute for Learning and Memory
- Spectroscopy Laboratory
- Whitehead Institute for Biomedical Research

Collaboration with the School of Engineering
One of the great strengths of MIT is that school and departmental boundaries are invisible. Many science faculty members carry out research in collaboration with others in the School of Engineering. Often they are members of inter-school laboratories, such as the Center for Materials Science and Engineering, the Research Laboratory of Electronics, or the Institute for Soldier Nanotechnologies or the Koch Institute for Integrative Cancer Research. Sometimes they participate in joint programs, such as the Singapore–MIT Alliance or the Computation and Systems Biology program. And often research in science is facilitated by the superb facilities developed to support engineering research and education, such as the Microsystems Technology Laboratories.

Refer to the section on Interdisciplinary Research and Study in Part 1 for detailed descriptions of the centers and laboratories. 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 section in Part 2.

Publications
Brochures describing the academic programs and research centers are available through each department; contact the appropriate academic officer directly.

Office of the Dean
Marc A. Kastner, PhD
Donner Professor of Physics
Dean
Hazel Louise Sive, PhD
Professor of Biology
Member, Whitehead Institute for Biomedical Research
Associate Dean
Elizabeth Chadis, BA
Assistant Dean for Development
Ronald E. Hasseltine, BA
Assistant Dean for Finance
Heather G. Williams, MA
Assistant Dean for Administration and Human Resources
# Degrees Offered in the School of Science

## Biology  Course 7

<table>
<thead>
<tr>
<th>Degree</th>
<th>Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB</td>
<td>Biology</td>
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<tr>
<td>PhD</td>
<td>Biology</td>
</tr>
<tr>
<td>PhD</td>
<td>Biochemistry</td>
</tr>
<tr>
<td>PhD</td>
<td>Biological Oceanography (jointly offered with WHOI)</td>
</tr>
<tr>
<td>PhD</td>
<td>Biophysical Chemistry and Molecular Structure</td>
</tr>
<tr>
<td>PhD</td>
<td>Cell Biology</td>
</tr>
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<td>PhD</td>
<td>Computational and Systems Biology</td>
</tr>
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<td>PhD</td>
<td>Developmental Biology</td>
</tr>
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<td>Genetics</td>
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<td>PhD</td>
<td>Immunology</td>
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<td>Molecular Biology</td>
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<td>PhD</td>
<td>Neurobiology</td>
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## Brain and Cognitive Sciences  Course 9

<table>
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<tr>
<th>Degree</th>
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<td>SB</td>
<td>Brain and Cognitive Sciences</td>
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<tr>
<td>PhD</td>
<td>Cognitive Science</td>
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<td>PhD</td>
<td>Neuroscience</td>
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## Chemistry  Course 5

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<th>Degree</th>
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<tbody>
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<td>SB</td>
<td>Chemistry</td>
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<tr>
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<td>Inorganic Chemistry</td>
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## Computational and Systems Biology  Course CSB

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<tbody>
<tr>
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<td>Computational and Systems Biology (jointly offered with the School of Engineering)</td>
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</table>

## Earth, Atmospheric, and Planetary Sciences  Course 12

<table>
<thead>
<tr>
<th>Degree</th>
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<tr>
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<td>SM</td>
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<tr>
<td>SM</td>
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<tr>
<td>SM</td>
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<tr>
<td>SM</td>
<td>Marine Geology and Geophysics (jointly offered with WHOI)</td>
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<tr>
<td>SM</td>
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<tr>
<td>PhD, ScD</td>
<td>Climate Physics and Chemistry</td>
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<tr>
<td>PhD, ScD</td>
<td>Geochemistry</td>
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<td>PhD, ScD</td>
<td>Geophysics</td>
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<td>PhD, ScD</td>
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<tr>
<td>PhD, ScD</td>
<td>Planetary Sciences</td>
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## Mathematics  Course 18

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<tr>
<td>SB</td>
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<tr>
<td>SB</td>
<td>Mathematics with Computer Science</td>
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<td>PhD</td>
<td>Mathematics</td>
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## Physics  Course 8

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<td>SM</td>
<td>Physics</td>
</tr>
<tr>
<td>PhD</td>
<td>Physics</td>
</tr>
</tbody>
</table>

### 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.

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50 See Interdisciplinary Graduate Programs section in Part 2.
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 GIRs, 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 7.02/10.702 or 20.109, and one subject from this list of approved CI-M subjects for Course 7-A: 3.014, 5.36, 5.38, 7.19, 8.13, 9.02, 9.12, 9.18, 9.63, 10.26, 10.27, 10.28, 10.29, 20.380, or 2.791/6.021/20.370J. Further details on the 7-A major and CI-M subjects may be obtained from the department. Additional information regarding undergraduate academic programs and research opportunities may be obtained from the Biology Education Office, Room 68-120, 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:
7.02/10.702 or 20.109; 7.06, 7.08J, 7.20J, 7.21, 7.22, 7.23, 7.24, 7.25, 7.27, 7.28, 7.29J, 7.31, 7.32J, 7.35, 7.36, and 7.37J.

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 onco genes, 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 for generating the diversity of cell types that arise during development, and controlling the ways in which cells interact to produce organ systems and whole organisms. These problems are studied using vertebrates, invertebrates, and plants. Specific topics of interest include the regulation of gene expression, cell interactions, cell lineages, cell migrations, sex determination, stem cells, and cloning.

Genetics/microbiology includes genetic analyses of fundamental problems in bacteria, bacteriophage, viruses, and yeast. Areas of specific interest include protein secretion, DNA transposition, protein turnover, DNA synthesis and repair, mechanisms of genetic recombination, and electron transport in mitochondria. More complex problems under study are cellular responses to stress, plant-bacterial interactions, high resolution structure-function studies of proteins and RNAs, and the control circuits regulating gene expression. A new area of study
is the application of high resolution molecular techniques to problems in human genetics. 

**Immunology** is the study of the genetic, cellular, and molecular mechanisms underlying the exquisite sensitivity and specificity of the immune system. The immunology group studies the chemistry of antigen-antibody and antigen-T cell receptor interactions, using the tools of molecular biology as well as classical immunological approaches. Of particular interest is the role of idiotypic and cellular interactions in the regulation of the immune system as studied by organ culture, hybridoma technology, and the behavior of transgenic mice.

**Neurobiology** is an area of recent emphasis in the department. The subject in general neurobiology is supplemented by a seminar series and an interlaboratory journal club. The emphasis is molecular, primarily using cell-biological, developmental, and genetic approaches. Present areas of research interest include the molecular determinants of neuronal diversity and shape; of cell-adhesive, cell-inductive, and synaptic interactions; and the genetic and molecular determinants of cell-lineages, memory storage, and sensory transduction.

**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, 617-253-3717, gradbio@mit.edu.

**FACULTY AND STAFF**

**Faculty and Teaching Staff**

Chris Kaiser, PhD  
Professor of Biology  
MacVicar Faculty Fellow  
Department Head  
Uttam L. RajBhandary, PhD  
Lester Wolfe Professor of Molecular Biology  
Associate Head

**Professors**

Angelika Amon, PhD  
Professor of Biology  
Howard Hughes Medical Institute Investigator  
Tania Baker, PhD  
Whitehead Professor of Biology  
Howard Hughes Medical Institute Investigator  
MacVicar Faculty Fellow  
David Bartel, PhD  
Professor of Biology  
Howard Hughes Medical Institute Investigator  
Member, Whitehead Institute for Biomedical Research  
Stephen Bell, PhD  
Professor of Biology  
Howard Hughes Medical Institute Investigator  
Jianzhu Chen, PhD  
Professor of Biology  
Howard Hughes Medical Institute Investigator  
Sallie W. Chisholm, PhD  
Cottrell Professor of Immunology  
Catherine L. Drennan, PhD  
Howard Hughes Medical Institute Investigator  
David F. Cottrell Professor of Immunology  
Howard Hughes Medical Institute Investigator  
Gerald R. Fink, PhD  
ACS Professor of Genetics  
Member, Whitehead Institute for Biomedical Research  
Frank Gertler, PhD  
Ross Scholar Professor of Biology  
Alan Davis Grossman, PhD  
Praecis Professor of Biology  
Chris Kaiser, PhD
Leonard Pershing Guarente, PhD
Novartis Professor of Biology

Nancy Haven Hopkins, PhD
Amgen Professor of Biology

H. Robert Horvitz, PhD
David H. Koch Professor of Biology
Howard Hughes Medical Institute Investigator

David Evan Housman, PhD
Ludwig Professor for Cancer Research and Biology

Richard Olding Hynes, PhD
Ludwig Professor for Cancer Research
Howard Hughes Medical Institute Investigator

Barbara Imperiali, PhD
Ellen Swallows Richards Professor of Chemistry
Professor of Biology

Tyler Edwards Jacks, PhD
Koch Professor of Biology
Howard Hughes Medical Institute Investigator
Director, David H. Koch Institute for Integrative Cancer Research

Rudolf Jaenisch, MD
Professor of Biology
Member, Whitehead Institute for Biomedical Research

Jonathan Alan King, PhD
Professor of Biology

Monty Krieger, PhD
Professor of Biology
Whitehead Professor of Molecular Genetics
Charles F. Hopewell Faculty Fellow

Eric S. Lander, PhD
Professor of Biology
Member, Whitehead Institute for Biomedical Research
Director, Broad Institute

Douglas Lauffenburger, PhD
Whitaker Professor of Bioengineering, Chemical Engineering, and Biology
Head, Biological Engineering Department

Jacqueline Lees, PhD
Professor of Biology
Ludwig Scholar
Associate Director, David H. Koch Center for Integrative Cancer Research

Susan L. Lindquist, PhD
Professor of Biology
Member, Whitehead Institute for Biomedical Research
Howard Hughes Medical Institute Investigator

Harvey Franklin Lodish, PhD
Professor of Biology and Bioengineering
Member, Whitehead Institute for Biomedical Research

Paul Thomas Matsudaira, PhD
Professor of Biology and Bioengineering
Member, Whitehead Institute for Biomedical Research
Director, Whitehead Institute for Biomedical Research

Dianne K. Newman, PhD
John and Dorothy Wilson Professor of Biology
Howard Hughes Medical Institute Investigator

Terry L. Orr-Weaver, PhD
American Cancer Society Professor of Biology
Member, Whitehead Institute for Biomedical Research

David Conrad Page, MD
Professor of Biology
Howard Hughes Medical Institute Investigator
Director, Whitehead Institute for Biomedical Research

Mary Lou Pardue, PhD
Boris Magasanik Professor of Biology

Hidde Ploegh, PhD
Professor of Biology
Member, Whitehead Institute for Biomedical Research

William G. Quinn, PhD
Professor of Neurobiology

Alexander Rich, MD
William Thompson Sedgwick Professor of Biophysics

Leona Samson, PhD
American Cancer Society Professor
Professor of Toxicology and Biological Engineering
Director, Center for Environmental Health Sciences

Robert Thomas Sauer, PhD
Luria Professor of Biology

Phillip Allen Sharp, PhD
Institute Professor

Morgan H. Sheng, MBBS, PhD
Professor of Neuroscience
Howard Hughes Medical Institute Investigator

Anthony John Sinskey, ScD
Professor of Microbiology

Hazel Louise Sive, PhD
Professor of Biology
Member, Whitehead Institute for Biomedical Research
Associate Dean of Science

Lisa Amelia Steiner, MD
Professor of Immunology

JoAnne Stubbe, PhD
Novartis Professor of Chemistry and Biology

Susumu Tonegawa, PhD
Picower Professor of Biology and Neuroscience
Howard Hughes Medical Institute Investigator

Graham Charles Walker, PhD
American Cancer Society Professor of Biology

Robert Allen Weinberg, PhD
Ludwig Professor for Cancer Research
American Cancer Society Professor of Biology
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Matthew Wilson, PhD
Professor of Neurobiology

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Member, Whitehead Institute for Biomedical Research

Christopher Burge, PhD
Associate Professor of Biology

Amy Keating, PhD
Sizer Career Development Associate Professor of Biology

Troy Littleton, MD, PhD
Middleton Associate Professor of Neurobiology

Carlos Lois, MD, PhD
Associate Professor of Neurobiology

Christopher Burge, PhD
Associate Professor of Biology

Amy Keating, PhD
Sizer Career Development Associate Professor of Biology

Troy Littleton, MD, PhD
Middleton Associate Professor of Neurobiology

Carlos Lois, MD, PhD
Associate Professor of Neurobiology
Elly Nedivi, PhD  
Associate Professor of Neurobiology

David Sabatini, PhD  
Linda and Howard Stern Career Development  
Associate Professor of Biology  
Howard Hughes Medical Institute Investigator  
Associate Member, Whitehead Institute for  
Biomedical Research

Michael B. Yaffe, MD, PhD  
Associate Professor of Biology

Laurie A. Boyer, PhD  
Assistant Professor of Biology

Paul Chang, PhD  
Assistant Professor of Biology

Iain Cheeseman, PhD  
Assistant Professor of Biology  
Associate Member, Whitehead Institute for  
Biomedical Research

Michael Hemann, PhD  
Assistant Professor of Biology

Dennis Kim, PhD  
Swanson Career Development Assistant  
Professor of Biology

Michael Laub, PhD  
Assistant Professor of Biology

Peter Reddien, PhD  
Assistant Professor of Biology  
Associate Member, Whitehead Institute for  
Biomedical Research

Aviv Regev, PhD  
Assistant Professor of Biology

Jeroen P. J. Saeij, PhD  
Assistant Professor of Biology

Thomas Schwartz, PhD  
Pfizer-Laubach Career Development Assistant  
Professor of Biology

Instructor, Outreach Coordinator  
Mandana Sassanfar, PhD  

Research Staff

Research Scientists  
Alexander Athanasiadis, PhD  
Paolo Bocazzi, PhD  
Sanjay DSouza, PhD  
Katherine E. Gibson, PhD  
Robert Grant, PhD  
Kathryn M. Jones, PhD  
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T. Sambandan, PhD  
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Professors Emeriti  
David Baltimore, PhD  
Professor of Biology, Emeritus

Gene Brown, PhD  
Professor of Biochemistry, Emeritus

Arnold Lester Demain, PhD  
Professor of Industrial Microbiology, Emeritus

Herman Nathaniel Eisen, MD  
Professor of Immunology, Emeritus  
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Maurice Sanford Fox, PhD  
Professor of Molecular Biology, Emeritus

Malcolm Lawrence Gefter, PhD  
Professor of Biochemistry, Emeritus

Har Gobind Khorana, PhD  
Alfred P. Sloan Professor of Biology and  
Chemistry, Emeritus  
Senior Lecturer

Irving M. London, MD  
Grover M. Hermann Professor of Health Sciences  
and Technology, Emeritus  
Professor of Biology and Medicine, Emeritus

Boris Magasanik, PhD  
Jacques Monod Professor of Microbiology,  
Emeritus  
Senior Lecturer

Sheldon Penman, PhD  
Professor of Cell Biology, Emeritus

Phillips Wesley Robbins, PhD  
Professor of Biochemistry, Emeritus

Robert Daniel Rosenberg, MD, PhD  
Whitehead Professor of Biology  
Professor of Medicine, Harvard Medical School

Paul Reinhard Schimmel, PhD  
John D. MacArthur Professor of Biochemistry and  
Biophysics, Emeritus

Ethan Royal Signer, PhD  
Professor of Biology, Emeritus

Annamaria Torriani, PhD  
Professor of Biology, Emerita  
Senior Lecturer

Stephanie Capaldi, PhD  
Michelle Mischke, PhD  
Allice Rushforth, PhD  
Diviya Sinha, PhD  
Katerina Zagriadskaya, PhD

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Senior Lecturer
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, neuroscience, 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.
**Bachelor of Science in Brain and Cognitive Sciences/Course 9**

<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></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>6</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>8</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement {can be satisfied by a laboratory in the Departmental Program}</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Total GiR Subjects Required for SB Degree</strong></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>Required Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.00 Introduction to Psychology, 12, HASS</td>
<td>126–132</td>
</tr>
<tr>
<td>9.01 Introduction to Neuroscience, 12, REST; Physics II (GIR)</td>
<td></td>
</tr>
<tr>
<td>9.07 Statistics for Brain and Cognitive Sciences, 12; Calculus II (GIR)*</td>
<td></td>
</tr>
</tbody>
</table>

**Core Subjects**

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.

### Cognitive Science

- 9.34 Sensory and Social Orders, 9; 9.00*
- 9.37 Anigrafs, 9; 9.34*
- 9.36 Abnormal Language, 12; 24.900*
- 9.37 Language Acquisition, 12, HASS; 24.900*
- 9.50 Psycholinguistics, 12, HASS; 24.900* or 9.00
- 9.65 Cognitive Processes, 12, HASS; 9.00
- 9.66 Computational Cognitive Science, 12; 9.07, 18.05, 6.041, or permission of instructor
- 9.85 Infant and Early Childhood Cognition, 12; 9.00
- 24.900 Introduction to Linguistics, 12, HASS-D, CI-H

### Cognitive Neuroscience

- 9.20 Cognitive Neuroscience, 12; 9.01
- 9.20 Animal Behavior, 12, HASS; 9.00*
- 9.22 A Clinical Approach to the Human Brain, 12
- 9.35 Sensation and Perception, 12; Physics II (GIR), Calculus II (GIR); or permission of instructor
- 9.71 Functional MRI of High-Level Vision, 12, CI-M; 9.07; 9.34, 9.35, 9.65, 9.66, or permission of instructor

### Neuroscience

- 9.03 Neural Basis of Learning and Memory, 12; 9.01
- 9.04 Neural Basis of Vision and Audition, 12; 9.01*
- 9.05 Neural Basis of Movement, 12; 9.01*
- 9.09a Cellular Neurobiology, 12; 7.05
- 9.14 Brain Structure and Its Origins, 12, 9.01
- 9.15 Biochemistry and Pharmacology of Synaptic Transmission, 12; 9.01, 7.05, or permission of instructor
- 9.18 Developmental Neurobiology, 12, CI-M; 9.01, 7.03, 7.05, or permission of instructor
- 9.24 Diseases of the Nervous System, 12; 9.01
- 9.29 Introduction to Computational Neuroscience, 12; 18.03, Physics II (GIR); or permission of instructor
- 9.31 Neurophysiology of Memory, 12; 9.01

### Laboratory

One of the following is required:

- 9.02 Systems Neuroscience Laboratory, 12, Lab, CI-M; 9.01
- 9.02B Experimental Molecular Neurobiology, 12, Lab, CI-M; 9.01, Biology (GIR)
- 9.61 Laboratory in Higher-Level Cognition, 12, Lab, CI-M; 9.07; 9.35, 9.59, 9.66, 9.65, 9.85, or permission of instructor
- 9.63 Laboratory in Visual Cognition, 12, Lab, CI-M; 9.07; 9.06, 9.01, or permission of instructor

Plus one of the following:

- 9.0U Research Undergraduate Research, 12
- 9.02 Brain Laboratory, 12, Lab, CI-M; 9.01
- 9.12 Experimental Molecular Neurobiology, 12, Lab, CI-M; 9.01, Biology (GIR)
- 9.30 Research in Brain and Cognitive Sciences, 12, Lab; 9.00*
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 to 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-semester 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, 617-253-7403, or visit http://web.mit.edu/bcs/.
FACULTY AND STAFF

Faculty and Teaching Staff
Mriganka Sur, PhD
Paul E. Newton Professor of Neuroscience
Department Head
Matthew Wilson, PhD
Sherman Fairchild Professor of Neurobiology
Associate Head

Professors
Edward H. Adelson, PhD
Professor of Visual Sciences
Mark Bear, PhD
Picower Professor of Neuroscience
Howard Hughes Medical Institute Investigator
Director, Picower Institute for Learning and Memory
Robert Cregar Berwick, PhD
Professor of Computational Linguistics
Emilio Bizzi, MD
Institute Professor
Emery N. Brown, MD, PhD
Professor of Computational Neuroscience and Health Sciences and Technology
Stephan Lewis Chorover, PhD
Professor of Psychology
Martha Constantine-Paton, PhD
Professor of Biology
Suzanne Corkin, PhD
Professor of Behavioral Neuroscience
Robert Desimone, PhD
Professor of Neuroscience
Director, McGovern Institute for Brain Research
John D. E. Gabrieli, PhD
Grover Hermann Professor of Health Sciences and Technology and Cognitive Neuroscience
Director, Martinos Imaging Center at the McGovern Institute for Brain Research
Codirector, Clinical Research Center
Edward A. F. Gibson, PhD
Professor of Cognitive Sciences
Ann Martin Graybiel, PhD
Mitsui Career Development Assistant Professor of Neuroanatomy
Alan Hein, PhD
Professor of Experimental Psychology
Susan Hockfield, PhD
Professor of Neuroscience
President, MIT
Neville Hogan, PhD
Professor of Mechanical Engineering
Nancy G. Kanwisher, PhD
Ellen Swallows Richards Professor of Cognitive Neuroscience
MacVicar Faculty Fellow
Earl K. Miller, PhD
Picower Professor of Visual Neuroscience
Associate Director, Picower Institute for Learning and Memory
Tomaso Armando Poggio, PhD
Eugene McDermott Professor in the Brain Sciences and Human Behavior
Director, Center for Biological and Computational Learning
Mary Crawford Potter, PhD
Professor of Psychology
Drazen Prelec, PhD
Digital Equipment Corporation Leaders for Manufacturing Professor of Management
Professor of Economics and Brain and Cognitive Sciences
William G. Quinn, PhD
Professor of Neurobiology
Whitman Albin Richards, PhD
Professor of Cognitive Sciences
Peter Harkai Schiller, PhD
Dorothy W. Poitras Professor in Medical Engineering and Medical Physics
Gerald Edward Schneider, PhD
Professor of Neuroscience
H. Sebastian Seung, PhD
Professor of Computational Neuroscience
Howard Hughes Medical Institute Investigator
Morgan Hwa-Tze Sheng, MD, PhD
Menicon Professor of Neurobiology
Howard Hughes Medical Institute Investigator
Jean-Jacques Slotine, PhD
Professor of Mechanical Engineering and Information Sciences
Director, Nonlinear Systems Laboratory
Susumu Tonegawa, PhD
Picower Professor of Biology and Neuroscience
Howard Hughes Medical Institute Investigator
Director, MIT/Riken Center
Li-Huei Tsai, PhD
Picower Professor of Neuroscience
Howard Hughes Medical Institute Investigator
Kenneth N. Wexler, PhD
Professor of Psychology and Linguistics
Richard Jay Wurtman, MD
Cecil H. Green Distinguished Professor of Neuropharmacology

Associate Professors
James DiCarlo, MD, PhD
Associate Professor of Neuroscience
Michale Fee, PhD
Associate Professor of Neuroscience
Alan Jasanoff, PhD
Norman C. Rasmussen Career Development Associate Professor of Nuclear Science and Engineering and Biological Engineering
J. Troy Littleton, MD, PhD
Fred and Carole Middleton Associate Professor of Biology
Christopher Moore, PhD
Mitsui Career Development Associate Professor of Neuroscience
Elly Nedivi, PhD
Associate Professor of Neurobiology
Aude Oliva, PhD
Associate Professor of Cognitive Neuroscience
Pawan Sinha, PhD
Associate Professor of Computational Neuroscience
Joshua Tenenbaum, PhD
Associate Professor of Cognitive Science

Assistant Professors
Edward S. Boyden, PhD
Benesse Career Development Assistant Professor of Biomedical Engineering
Ki Ann Goosens, PhD
Assistant Professor of Neuroscience
Yasunori Hayashi, PhD
Assistant Professor of Neurobiology
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, Francis Bitter Magnet Laboratory, Harvard-MIT Division of Health Sciences and Technology, Institute for Soldier Nanotechnologies, Laboratory for Energy and the Environment, Lincoln Laboratory, and 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 participate 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 or Doctor of Science degree. 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 facilities and interdisciplinary laboratories.

For more information, visit 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, Chemical Engineering, and Biological Engineering.

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. 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 semesters have the option of preparing an undergraduate thesis.

### Minor Program in Chemistry

The requirements for a Minor in Chemistry are as follows:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.03</td>
<td>Principles of Inorganic Chemistry I</td>
</tr>
<tr>
<td>5.12</td>
<td>Organic Chemistry I</td>
</tr>
<tr>
<td>5.310</td>
<td>Laboratory Chemistry</td>
</tr>
<tr>
<td>5.60</td>
<td>Thermodynamics and Kinetics</td>
</tr>
</tbody>
</table>

Two additional subjects from the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.04</td>
<td>Principles of Inorganic Chemistry II</td>
</tr>
<tr>
<td>5.07</td>
<td>Biological Chemistry I</td>
</tr>
<tr>
<td>5.08</td>
<td>Biological Chemistry II</td>
</tr>
<tr>
<td>5.13</td>
<td>Organic Chemistry II</td>
</tr>
<tr>
<td>5.36</td>
<td>Biochemistry and Organic Laboratory</td>
</tr>
<tr>
<td>5.36U*</td>
<td>Biochemistry and Organic Laboratory</td>
</tr>
<tr>
<td>5.37</td>
<td>Organic and Inorganic Laboratory</td>
</tr>
<tr>
<td>5.37U*</td>
<td>Organic and Inorganic Laboratory</td>
</tr>
<tr>
<td>5.43</td>
<td>Advanced Organic Chemistry</td>
</tr>
<tr>
<td>5.61</td>
<td>Physical Chemistry</td>
</tr>
<tr>
<td>5.62</td>
<td>Physical Chemistry</td>
</tr>
</tbody>
</table>

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

### Inquiries

Additional information may be obtained from the Chemistry Education Office, Room 2-204, 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

*Students may complete 12 units from any combination of the modules in 5.36U and 5.37U (counted as one subject).
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, 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 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

<table>
<thead>
<tr>
<th>Required Subjects</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement (one subject can be satisfied by 5.111 or 5.112 in the Departmental Program)</td>
<td>6</td>
<td>132</td>
</tr>
<tr>
<td>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)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement (can be satisfied by completing all three modules in 5.35 in the Departmental Program)</td>
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<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>Required Subjects</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.03 Principles of Inorganic Chemistry I, 12; 5.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.07 Biological Chemistry I, 12; 5.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.111 or 5.112 Principles of Chemical Science, 12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>5.12 Organic Chemistry I, 12, REST; Chemistry (GIR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.13 Organic Chemistry II, 12; 5.12</td>
<td></td>
<td></td>
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<tr>
<td>5.25 Introduction to Experimental Chemistry, 12, LAB</td>
<td>Module 1 Survey of Spectroscopy, 4; Chemistry (GIR) Module 2 Inorganic Synthesis and Kinetics, 4; Chemistry (GIR), Module 3 Polymeric Light Emitting Devices, 4; Chemistry (GIR), 5.12, Module 2</td>
<td></td>
</tr>
<tr>
<td>5.36 Biochemistry and Organic Laboratory, 12, CI-M</td>
<td>Module 4 Expression and Purification of Enzyme Mutants, 4; 5.07 or 5.05; Module 2 or 5.310; Module 5</td>
<td></td>
</tr>
<tr>
<td>5.37 Organic and Inorganic Laboratory, 12</td>
<td>Module 5 Kinetics of Enzyme Inhibition, 4; 5.07 or 5.05; Module 2 or 5.310; Module 4 Module 6 Organic Structure Determination, 4; 5.12; Module 2 or 5.310; 5.13</td>
<td></td>
</tr>
<tr>
<td>5.38 Physical Chemistry Laboratory, 12, CI-M</td>
<td>Module 7 Introduction to Organic Synthesis, 4; 5.13, Module 6 Module 8 Two-Electron Bond, 4; 5.03, 5.61, Module 6 Module 9 Dinitrogen Cleavage, 4; 5.03, 5.61, Module 6</td>
<td></td>
</tr>
<tr>
<td>5.43 Advanced Organic Chemistry, 12</td>
<td>Module 10 Quantum Dots, 4; 5.61, Module 7 Module 11 Time Resolved Molecular Spectroscopy, 4; 5.61; 5.07 or 7.05; Module 5 Module 12 Solid State NMR, 4; 5.61; 5.07 or 7.05; Module 5 Module 5</td>
<td></td>
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<tr>
<td>5.60 Thermodynamics and Kinetics, 12, REST; Calculus II (GIR), Chemistry (GIR)</td>
<td></td>
<td></td>
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<tr>
<td>5.61 Physical Chemistry, 12, REST; Physics II (GIR), Calculus II (GIR), Chemistry (GIR)</td>
<td></td>
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</tr>
<tr>
<td>Restricted Electives</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>At least two of the following four subjects:</td>
<td></td>
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<tr>
<td>5.04 Principles of Inorganic Chemistry II, 12; 5.03</td>
<td></td>
<td></td>
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<tr>
<td>5.08 Biological Chemistry II, 12; 5.12; 5.07 or 7.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.43 Advanced Organic Chemistry, 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.62 Physical Chemistry, 12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Departmental Program Units That Also Satisfy the GIRs                           | (36)    |       |
| Unrestricted Electives                                                          | 60      |       |
| Total Units Beyond the GIRs Required for SB Degree                              | 180     |       |

Notes

- Alternate prerequisites are listed in the subject description.
- (i) 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.
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. All students are required to serve as a teaching assistant during the first year.

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, 617-253-1845.
Research Staff

Sponsored Research Technical Staff
Anne Gorham, BS, MS
Experimental Applications Specialist

Robert J. Kennedy, III, PhD
Operations Manager

Li Li, BS
Research Specialist

Peter Mueller, PhD
Principal Research Scientist

Jeffrey Simpson, PhD
Director, Instrumentation Facility

Professors Emeriti
Robert Arnold Alberty, PhD, ScD
Professor of Chemistry, Emeritus

Klaus Biemann, PhD
Professor of Chemistry, Emeritus

Alan Davison, PhD
Professor of Chemistry, Emeritus

Carl Wesley Garland, PhD
Professor of Chemistry, Emeritus

Frederick Davis Greene II, PhD, ScD
Professor of Chemistry, Emeritus

Daniel Schaeffer Kemp, PhD
Professor of Chemistry, Emeritus

Har Gobind Khorana, PhD
Alfred P. Sloan Professor of Biology and Chemistry, Emeritus
Senior Lecturer

Irwin Oppenheim, PhD
Professor of Chemistry, Emeritus

Dietmar Seyferth, PhD
Robert T. Haslam and Bradley Dewey Professor of Chemistry, Emeritus

Jeffrey Irwin Steinfeld, PhD
Professor of Chemistry, Emeritus

John Stewart Waugh, PhD
Institute Professor, Emeritus
Professor of Chemistry, Emeritus

Gerald Norman Wogan, PhD
Professor of Chemistry, Emeritus
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 interdepartmental 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.

### Bachelor of Science in Earth, Atmospheric, and Planetary Sciences

#### Course 12

<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>8</td>
<td></td>
</tr>
<tr>
<td>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]</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td></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

**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; Physics II (GIR), Calculus II (GIR) (required for concentration Area 3 majors)
    - **12.003** Physics of the Atmosphere and Ocean, 12; Physics I (GIR), Calculus II (GIR); (required for concentration Area 2 and Area 4 majors)
    - **12.006** Nonlinear Dynamics I: Chaos, 12; Physics II (GIR), 18.03
  - One of the following mathematics subjects:
    - **18.03** Differential Equations, 12; REST; Calculus II (GIR)
    - **18.034** Differential Equations, 12, REST; Calculus II (GIR)
  - The following research subject:
    - **12.TIP** Thesis and Independent Study Preparation, 6
    - One of the following:
      - **12.IND** Independent Study (at least 6 units), CI-M; 12.TIP
      - **12.Thesis** 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; Physics II (GIR), Calculus II (GIR), 18.03
- **12.108** Structure of Earth Materials, 12; Chemistry (GIR)
- **12.122** Structural Geology, 12; 12.001, 12.005
- **5.60** Thermodynamics and Kinetics, 12; REST; Calculus II (GIR), Chemistry (GIR)
  - One of the following sets of field subjects:
    - **12.211** Field Geophysics, 6
    - **12.214** Environmental Geophysics, 12; 18.03
    - **12.222** Field Geophysics Analysis, 6, CI-M; 12.221
    - **12.114** Field Geology I, 6; 12.108, 12.213, or permission of instructor
    - **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; Calculus II (GIR), Chemistry (GIR)
- **8.03** Physics II, 12, REST; Physics II (GIR), Calculus II (GIR)
- **12.330** 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; Physics I (GIR), 18.03
    - **8.09** Classical Mechanics II, 12; Physics I (GIR)
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 Major Program/ Five-Year Program

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 major 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 in one year of additional study, particularly if programs are arranged for this purpose from the beginning of the fourth year.

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
- 12.006 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.

**Inquiries**
Additional information may be obtained from the department’s Education Office, Room 54-912, 617-253-3381.

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**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 curriculum. 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 Science, or in Climate Physics and Chemistry**
The General Institute Requirements for the degree of Master of Science in Earth and Planetary Science, in Atmospheric Science, or in Climate Physics and Chemistry are described under 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 climate and atmospheric science have access to the facilities of the joint MIT-WHOI program.

**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’s Education Office, Room 54-912, 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; electroseismic 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 new 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 54-1814, or by calling Professor Robert van der Hilst at 617-253-6977.

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://pooc.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, Room 54-422, 617-253-6308, jle@mit.edu, or visit 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 comput-
ers, 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 con-
tacting the director, Professor M. Nafi Toksöz,
Room E34-440, 617-253-7852, nafi@erl.mit.edu.

FACULTY AND STAFF

Faculty and Teaching Staff
Maria Zuber, PhD
Earle Griswold Professor of Geophysics and
Planetary Science
Department Head

Professors
Richard P. Binzel, PhD
Professor of Planetary Sciences
Samuel A. Bowring, PhD
Breene M. Kerr Professor of Geology
MacVicar Faculty Fellow
Edward Allen Boyle, PhD
Professor of Ocean Geochemistry
Burrell Clark Burchfiel, PhD
Schlumberger Professor of Geology
James Ludlow Elliot, PhD
Professor of Planetary Astronomy and Physics
Director, George R. Wallace, Jr., Astrophysical
Observatory
Kerry Andrew Emanuel, PhD
Breene M. Kerr Professor of Atmospheric Science
Dara Entekhabi, PhD
Professor of Civil and Environmental Engineering
and Earth, Atmospheric, and Planetary Sciences
J. Brian Evans, PhD
Professor of Geophysics
Glenn Richard Flierl, PhD
Professor of Oceanography
Frederick August Frey, PhD
Professor of Geochemistry
Timothy L. Grove, PhD
Professor of Geology
Bradford H. Hager, PhD
Cecil and Ida Green Professor of Earth Sciences
Thomas A. Herring, PhD
Professor of Geophysics
Richard Siegmund Lindzen, PhD
Alfred P. Sloan Professor of Meteorology
John C. Marshall, PhD
Professor of Atmospheric and Oceanic Sciences
F. Dale Morgan, PhD
Professor of Geophysics
Associate Director, Earth Resources Laboratory
Director, Kuwait-MIT Center
Raymond Alan Plumb, PhD
Professor of Meteorology
Director, Program in Atmospheres, Oceans and
Climate
Ronald George Prinn, ScD
TEPCO Professor of Atmospheric Chemistry
Director, Center for Global Change Science
Paola Malanotte Rizzoli, PhD
Professor of Physical Oceanography
Director, MIT-WHOI Joint Program
Daniel H. Rothman, PhD
Professor of Geophysics
Leigh H. Royden, PhD
Professor of Geology and Geophysics
Roger E. Summons, PhD
Professor of Geobiology
M. Nafi Toksöz, PhD
Professor of Geophysics
Director, George R. Wallace, Jr., Geophysical
Observatory
Robert van der Hilst, PhD
Professor of Geophysics
Director, Earth Resources Laboratory
Jack Wisdom, PhD
Professor of Planetary Sciences
Carl Isaac Wunsch, PhD
Cecil and Ida Green Professor of Physical
Oceanography

Associate Professors
Raffaele Ferrari, PhD
Associate Professor of Dynamical Oceanography
Sara Seager, PhD
Associate Professor of Extrasolar Planets

Assistant Professors
Tanya Bosak, PhD
Assistant Professor of Geobiology
Linda T. Elkins-Tanton, PhD
Assistant Professor of Geological Sciences
Oliver Jagoutz, PhD
Assistant Professor of Geology
Alison Malcolm, PhD
Assistant Professor of Theoretical Geophysics
Paul O’Gorman, PhD
Assistant Professor of Theoretical Geophysics

Visiting Professors
Yves Bernabé, PhD
Professor of Geophysics
Vernon F. Cormier, PhD
Professor of Geophysics
Martijn V. de Hoop, PhD
Professor of Geophysics
James Hansen, PhD
Professor of Atmospheric Dynamics

Senior Lecturer
Lodovica Illari, PhD
Research Staff

Senior Research Scientists
William Durham
Michael Fehler
Michael Follows

Principal Research Scientists
Robert W. King, Jr., PhD
Luisa T. Molina, PhD
Robert Reilinger, PhD
William Rodi, PhD
Chien Wang, PhD

Principal Research Engineer
Christopher Hill, BS

Research Engineer
Zhenya Zhu, PhD

Research Scientists
Eduardo Andrade Lima, PhD
Daniel Burns, PhD
Executive Director, Earth Resources Laboratory
Jean-Michel Campin, PhD
Christopher Carr, PhD
Nilanjan Chatterjee, PhD
Stephanie Dutkiewicz, PhD
Constantinos Evangelinos, PhD
Ming Fang, PhD
David Ferreira, PhD
Chris Forest, PhD
Gael Forget, PhD
Patrick Heimbach, PhD
Helen Hill, PhD
Armando M. Howard, PhD
Jin Huang, PhD
Sadi Kuleli, PhD
Simon McClusky, PhD
Malcolm Pringle, PhD
Jahandar Ramezani, PhD
Srinivas Ravela, PhD
Courtney Adam Schlosser, PhD
Jeffery Scott, PhD
Andrei Sokolov, PhD
Shan Sun, PhD
Raghothanam Sundararajan, PhD
Mark Willis, PhD
Haijian Zhang, PhD

Research Specialists
Richard Kayser, MS
Charmaine King, BS
Linda Meinke, BS
William Olszewski, PhD
Steven Silvan, PhD
Diana Spiegel, MS
Yunpeng Wang, PhD

Postdoctoral Associates
Astrid Johanna Baehr, PhD
Sheekela Baker-Yeboah, PhD
Naifang Bei, PhD
Laurent Carporzen, PhD
Alan Condon, PhD
Xiang Gao, PhD
Gill-Ran Jeong, PhD
Biqing Liang, PhD
Ying Lin, PhD
Manfredi Manizza, PhD
Guillaume Maze, PhD
Ulrich Mok, PhD
Michael Person, PhD
Matthew Rigby, PhD
Matthew Rioux, PhD
Noell Selin, PhD
Youshun Sun, PhD
John Taylor, PhD
Jun Wei, PhD

Postdoctoral Fellows
Daniel Abrams, PhD
Larissa Back, PhD
Noah Bechor Ben Dow, PhD
Andrea Castanho, PhD
Gang Chen, PhD
Chang Li, PhD
Benjamin Marzeion, PhD
Marcelo Mena, PhD
Ping Wang, PhD

Research Affiliates
Arthur Cheng, PhD
Robert Cicerone, PhD
Peter Clift, PhD
Benjamin Crosby, PhD
Norman Gaut, PhD
James Hirth, PhD
Christopher Koteas, PhD
Laurent Montesi, PhD
Delaine Reiter, PhD
Philip Reppert, PhD
Joseph B. Walsh, PhD
Wenlu Zhu, PhD

Visiting Scientists
Mark Behn, PhD
Thomas Burbine, PhD
Kevin Burke, PhD
Jesse Dann, PhD
Alan Faller, PhD
Geoffrey Gebbie, PhD
Levent Gulen, PhD
Sanjay Chayan Gupta, PhD
David Harkrider, PhD
John Hayes, PhD
Peter Huybers, PhD
Mary Krasovec, PhD
Malka Machlus, PhD
Ila Pillalamarri, PhD
Pui Ponte, PhD
Michael Prange, PhD
Dick Reesman, PhD
Carolyn Rupel, PhD
Lawrence Schwartz, PhD
Steven Singleton, PhD
Dirk Smit, PhD
Margaret Thompson, PhD
Peter Tilke, PhD
Robert Zartman, PhD

Professors Emeriti
William Francis Brace, PhD
Professor of Geology, Emeritus
Charles Claude Counselman III, PhD
Professor of Planetary Sciences, Emeritus
Theodore Richard Madden, PhD
Professor of Geophysics, Emeritus
Gordon Hemenway Pettengill, PhD
Professor of Planetary Physics, Emeritus
William F. Pinson, Jr., PhD
Associate Professor of Geology, Emeritus
M. Gene Simmons, PhD
Professor of Geophysics, Emeritus
John Brelsford Southard, PhD
Professor of Geology, Emeritus
Peter Hunter Stone, PhD
Professor of Climate Dynamics, Emeritus
The Department of Mathematics offers training at the undergraduate, graduate, and postgraduate levels. Its expertise covers 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.

Course 18 includes two undergraduate degrees: a Bachelor of Science in Mathematics and a Bachelor of Science in Mathematics with Computer Science. Undergraduate students may elect one of three options leading to the degree in mathematics: applied mathematics, theoretical mathematics, or general mathematics. The general mathematics option provides a great deal of flexibility and allows students to design their own programs in conjunction with their advisors. The Mathematics with Computer Science degree is offered for students who want to pursue interests in mathematics and theoretical computer science within a single undergraduate program.

At the graduate level, the Mathematics Department offers the PhD in Mathematics, which culminates in the exposition of original research in a dissertation. Graduate students also are given training and experience in the teaching of mathematics.

The C.L.E. Moore instructorships and Applied Mathematics instructorships bring mathematicians at the postdoctoral level to MIT and provide them with training in research and teaching.

For more information, visit 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 finance, physics, business, consulting, systems analysis, or actuarial science.

Because the career objectives of undergraduate mathematics majors are diverse, each student’s program is arranged through collaboration with his or her faculty advisor.

Undergraduates in mathematics are encouraged to elect an upper-level mathematics

---

### Bachelor of Science in Mathematics/Course 18

**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>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>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total GIR Subjects Required for SB Degree**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication Requirement</td>
<td>17</td>
</tr>
</tbody>
</table>

**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>Requirement</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>One of the following two subjects:</td>
<td>12</td>
</tr>
<tr>
<td>18.03 or 18.034 Differential Equations, 12; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives</td>
<td>96</td>
</tr>
</tbody>
</table>

To satisfy the requirements that students take two CI-M subjects, students must take two of the following subjects: 18.096, 18.100C, 18.104, 18.304, 18.384, 18.424, 18.434, 18.504, 18.704, 18.784, 18.821, 18.904, or 18.994 or one from the above list and one of the following subjects: 6.033, 8.06, or 18.310C.

**General Mathematics Option**

Eight 12-unit subjects of different content, including at least six advanced subjects (first decimal digit one or higher). One of these eight subjects must be 18.06, 18.700, or 18.701.

**Applied Mathematics Option**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.310 or 18.310C Principles of Applied Mathematics, 12; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.311 Principles of Applied Mathematics, 12; Calculus II (GIR), 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; Calculus II (GIR), 18.03*</td>
<td></td>
</tr>
<tr>
<td>18.112 Functions of a Complex Variable, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>One of the following two subjects:</td>
<td></td>
</tr>
<tr>
<td>18.06 Linear Algebra, 12; REST, Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.700 Linear Algebra, 12; REST, Calculus II (GIR)</td>
<td></td>
</tr>
</tbody>
</table>

Four additional 12-unit Course 18 subjects from the following two groups with at least one subject from each group:

*Group I—Probability and statistics, combinatorics, computer science*

*Group II—Numerical analysis, physical mathematics, nonlinear dynamics*

**Theoretical Mathematics Option**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.100 Analysis I, 12; Calculus II (GIR), 18.03*</td>
<td></td>
</tr>
<tr>
<td>18.701 Algebra I, 12; 18.700*</td>
<td></td>
</tr>
<tr>
<td>18.702 Algebra II, 12; 18.701</td>
<td></td>
</tr>
<tr>
<td>18.904 Introduction to Topology, 12; 18.100*</td>
<td></td>
</tr>
<tr>
<td>One of the following subjects:</td>
<td></td>
</tr>
<tr>
<td>18.101 Analysis II, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>18.102 Introduction to Functional Analysis, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>18.103 Fourier Analysis—Theory and Applications, 12; 18.100, 18.06*</td>
<td></td>
</tr>
</tbody>
</table>

An upper-level mathematics seminar in the Departmental Program [2 units]

Two additional Course 18 subjects of essentially different content, with the first decimal digit one or higher (24 units)

**Departmental Program Units That Also Satisfy the GIRs**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted Electives</td>
<td>60</td>
</tr>
</tbody>
</table>
Mathematics

The core of the program at MIT concerns the following principles and their various disciplines. The goal is to arrive at 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 also may wish to explore other topics such as logic, number theory, complex analysis, and subjects within applied mathematics.

The subjects 18.701 and 18.901 Introduction to Topology are more advanced and should not be elected until a student has had experience with proofs, as in 18.100 Analysis I or 18.700 Linear Algebra.

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.

This program allows 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) Mathematics for Computer Science or 18.310) to give experience with proofs and the necessary tools for analyzing algorithms; and complex systems (6.033 Computer System Engineering or 6.170 Laboratory in Software Engineering) in which mathematical issues may arise. The required subjects covering complexity (18.404) Theory of Computation or 18.400 Automata, Computability, and Complexity and algorithms (18.410 Design and Analysis of Algorithms) provide an introduction to the most theoretical aspects of computer science.

Some flexibility is allowed in this program. In particular, if students already have strong theorem-proving skills, they may substitute the more advanced subject 18.701 for 18.06, and 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, 617-253-2416. Additionally, the following information sheets are available in Room 2-108 and on the department website at http://www-math.mit.edu/undergraduate/:

What Math Subject Shall I Take?
Careers in Mathematics
Thinking of Majoring in Mathematics?

GRADUATE STUDY
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 described under Graduate Education in Part 1. The details of the departmental requirements are explained on the department’s website at http://math.mit.edu/graduate/. In outline, the requirements include a general qualifying examination to be taken in the third semester of registration in the program and completion of a minimum of 16 units (registration in at least 11 graduate subjects). The decisive requirement is original research in mathematics that is described in a thesis.

For students in the pure mathematics program, the oral part of the general examination

Bachelor of Science in Mathematics with Computer Science/Course 18-C

<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 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>

<table>
<thead>
<tr>
<th>Communication Requirement</th>
<th>Units</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 2 subjects designated as Communication Intensive in the Major (CI-M).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLUS Departmental Program Subject names below are followed by credit units, and by prerequisites, if any (corequisites in italics).</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Subjects</td>
<td>84-90</td>
</tr>
<tr>
<td>18.03 or 18.034 Differential Equations, 12, REST; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.410 Design and Analysis of Algorithms, 12; 6.006*</td>
<td></td>
</tr>
<tr>
<td>6.01 Introduction to EECS I, 12, 1/2 LAB</td>
<td></td>
</tr>
<tr>
<td>One subject from each of the following groups:</td>
<td></td>
</tr>
<tr>
<td>18.06 Linear Algebra, 12; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.700 Linear Algebra, 12; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.062J Mathematics for Computer Science, 12; Calculus I (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.310 Principles of Applied Mathematics, 12; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.310C Principles of Applied Mathematics, 12; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.400J Automata, Computability, and Complexity, 12; 6.042J</td>
<td></td>
</tr>
<tr>
<td>18.404J Theory of Computation, 12; 18.062J*</td>
<td></td>
</tr>
<tr>
<td>6.005 Principles of Software Development, 12; 6.01, 18.062*</td>
<td></td>
</tr>
<tr>
<td>6.033 Computer System Engineering, 12; 6.004</td>
<td></td>
</tr>
<tr>
<td>6.370 Laboratory in Software Engineering, 15; 6.005*</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives Four additional Course 18 subjects and two additional Course 6 subjects.</td>
<td>72</td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>To satisfy the requirements that students take two CI-M subjects, students must take two of the following subjects: 18.096, 18.100C, 18.101, 18.304, 18.424, 18.434, 18.504, 18.704, 18.784, 18.821, 18.904, or 18.994</td>
<td></td>
</tr>
<tr>
<td>or one from the above list and one of the following subjects: 6.033, 8.06, or 18.310C.</td>
<td></td>
</tr>
<tr>
<td>Departmental Program Units That Also Satisfy the GIRs</td>
<td>(27)</td>
</tr>
<tr>
<td>Unrestricted Electives</td>
<td>48-51</td>
</tr>
<tr>
<td>Total Units Beyond the GIRs Required for SB Degree</td>
<td>180</td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>

Notes
*Alternate prerequisites and corequisites 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.
tion 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 it becomes the field of specialization. The examiner in this area usually becomes the thesis advisor.

For students choosing the applied mathematics program, the basic objective is a proper balance of specialization and diversity. A range of subjects is required, including some in discrete and some in continuous applied mathematics. By the end of the first year of study, each student must submit a plan of study for approval by the chair 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
Nearly all 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, 617-253-2689.

FACULTY AND STAFF

Faculty and Teaching Staff
Michael Sipser, PhD
Professor of Applied Mathematics
Department Head
Tomasz S. Mrowka, PhD
Simons Professor of Mathematics
Chairman, Committee on Pure Mathematics
Michel X. Goemans, PhD
Leighton Family Professor of Applied Mathematics
Chairman, Committee on Applied Mathematics

Professors
Michael Artin, PhD
Professor of Mathematics
David J. Benney, PhD
Professor of Applied Mathematics
Bonnie A. Berger, PhD
Professor of Applied Mathematics
(On leave, fall)
Roman Bezrukavnikov, PhD
Professor of Mathematics
Hung Cheng, PhD
Professor of Applied Mathematics
Tobias H. Colding, PhD
Professor of Mathematics
Richard Mansfield Dudley, PhD
Professor of Mathematics
Alan Edelman, PhD
Professor of Applied Mathematics
Pavel I. Etingof, PhD
Professor of Mathematics
Daniel Z. Freedman, PhD
Professor of Applied Mathematics
Victor William Guillemin, PhD
Professor of Mathematics
Sigurdur Helgason, PhD
Professor of Mathematics
David S. Jerison, PhD
Professor of Mathematics
MacVicar Faculty Fellow
Victor Kac, PhD
Professor of Mathematics
Steven Kleiman, PhD
Professor of Mathematics
Daniel J. Kleitman, PhD
Professor of Applied Mathematics
F. Thomson Leighton, PhD
Professor of Applied Mathematics
George Lusztig, PhD
Norbert Wiener Professor of Mathematics
Arthur Paul Mattuck, PhD
Professor of Mathematics
James McKernan, PhD
Professor of Mathematics
Richard Burt Melrose, PhD
Simons Professor of Mathematics
Haynes R. Miller, PhD
Professor of Mathematics
MacVicar Faculty Fellow
Bjorn Poonen, PhD
Professor of Mathematics
Hartley Rogers, Jr., PhD
Professor of Mathematics
Rodolfo Ruben Rosales, PhD
Professor of Applied Mathematics
(On leave, spring)
Paul Seidel, PhD
Professor of Mathematics
Scott Sheffield, PhD
Professor of Mathematics
Peter W. Shor, PhD
Morss Professor of Applied Mathematics
Isadore Manuel Singer, PhD
Professor of Mathematics
Institute Professor
Gigliola Staffilani, PhD
Abby Rockefeller Mauze Professor of Mathematics
Richard P. Stanley, PhD
Levinson Professor of Applied Mathematics
W. Gilbert Strang, PhD
Professor of Mathematics
(On leave, spring)
Daniel W. Stroock, PhD
Professor of Mathematics
Alar Toomre, PhD
Professor of Applied Mathematics
David Alexander Vogan, Jr., PhD
Professor of Mathematics

Associate Professors
Denis S. Auroux, PhD
Associate Professor of Mathematics
John W. Bush, PhD
Associate Professor of Applied Mathematics
Lars Hesselholt, PhD
Associate Professor of Mathematics
(On leave, fall)
Kirans. Kedlaya, PhD
Cecil and Ida B. Green Career Development
Associate Professor of Mathematics
Ju-Lee Kim, PhD
Associate Professor of Mathematics
Jacob A. Lurie, PhD
Associate Professor of Mathematics
Alexander Postnikov, PhD
Associate Professor of Applied Mathematics (On leave, fall)

Assistant Professors
Mark J. Behrens, PhD
Assistant Professor of Mathematics
Benjamin B. Brubaker, PhD
Assistant Professor of Mathematics
Steven G. Johnson, PhD
Assistant Professor of Applied Mathematics
Jonathan A. Kelner, PhD
KDD Career Development Assistant Professor of Applied Mathematics
Abhinav Kumar, PhD
Assistant Professor of Mathematics
Lie Wang, PhD
Assistant Professor of Mathematics
Katrin Wehrheim, PhD
Rockwell International Career Development
Assistant Professor of Mathematics

Visiting Professors
Soren Galatius, PhD
Assistant Professor of Mathematics
Mikio Furuta, PhD
Professor of Mathematics
Jeffrey Kahn, PhD
Professor of Mathematics

Senior Lecturer
John B. Lewis, PhD

Lecturers
Dan Gutfreund, PhD
Aslan Kasimov, PhD

CLE Moore Instructors
Sami H. Assaf, PhD
Alina Ioana Bucur, PhD
Scott Carnahan, PhD
Pokman Cheung, PhD
Hans P. Christianson, PhD (On leave, fall)
David Jeremy Copeland, PhD
Michael Eichmair, PhD
Wen-Chuan Hu, PhD
Vera Mikyoung Hur, PhD
Todd A. Kemp, PhD
Liat Kessler, PhD
Brett L. Kotschwar, PhD
Ralf-Enno Lenzmann, PhD
Lionel Levine, PhD
Ivan Loseu, PhD
Grace K. Lyu, PhD
Karl E. Mahlburg, PhD
Mia Minnes, PhD
Yi Ni, PhD
Yaron Ostrover, PhD
Thomas Andrew Putnam, PhD
Martin Reiris, PhD
Travis Schedler, PhD
Junecue Suh, PhD
Craig Van Coevering, PhD
Benjamin T. Webster, PhD
David J. Whitehouse, PhD
Chenyang Xu, PhD (On leave)

Applied Mathematics Instructors
Yossi Farjoun, PhD
Sungwhan Jung, PhD
Avshalom Manela, PhD
Gregg Musiker, PhD
Jean-Christophe Nave, PhD
Pedro Miguel Reis, PhD
Benjamin Seibold, PhD
Daniel See-Wai Tam, PhD
Jerome Waldspuhl, PhD
Josephine Yu, PhD

Pure Mathematics Instructors
Cameron Freer, PhD
Sikimeti Ma’u, PhD

Research Staff

Postdoctoral Research Associate
Matthew Hedden, PhD
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 10²⁶ 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 (UROP) project. 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 nontraditional, 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.

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, biological physics, condensed matter, plasma, and nuclear and particle physics, allow students to gain an appreciation of the forefronts 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, 8.225, or 8.287. 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** 36–48
- **Astrophysics** 48–93
- **Planetary Astronomy** 208–312
- **Observations** 180–231
- **Independent Project in Astronomy** 309–403

Four of the subjects used to satisfy the requirements for the astronomy minor may not be used to satisfy any other minor or major.

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### Bachelor of Science in Physics/Course 8

<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</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 by 8.03 or 8.04, and 18.03 or 18.034 in the Departmental Program]</td>
<td>1</td>
</tr>
<tr>
<td>Laboratory Requirement (satisfied by 8.13 or equivalent in the Departmental Program)</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 are indicated in italics).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
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<tbody>
<tr>
<td>8.03</td>
<td>75–132</td>
</tr>
<tr>
<td>8.04</td>
<td>18.03*</td>
</tr>
</tbody>
</table>

**Physics: Flexible Option**

One of the following subjects:

- **8.05 Quantum Physics II, 12; 8.04**
- **8.20 Introduction to Special Relativity, 9, REST; Physics I (GIR), Calculus I (GIR)**
- **8.033 Relativity, 12; Physics I (GIR), Calculus II (GIR)**

One of the following experimental experiences:

- **8.13 Experimental Physics I, 18, LAB, CI-M; 8.04**
- **8.14 Experimental Physics II, 18, LAB; 8.05, 8.13**

**Physics: Focused Option**

- **8.033 Relativity, 12; Physics I (GIR), Calculus II (GIR)**
- **8.05 Quantum Physics II, 12; 8.04**
- **8.06 Quantum Physics III, 12, CI-M; 8.05**
- **8.13 Experimental Physics I, 18, LAB, CI-M; 8.04**
- **8.14 Experimental Physics II, 18, LAB; 8.05, 8.13**

**Thesis (12 units)**

#### Restricted Electives

- **Physics: Flexible Option** 36–48
- **Physics: Focused Option** 36–48

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 (36 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

<table>
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<tr>
<th>Units</th>
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<tr>
<td>24–36</td>
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</table>

#### Unrestricted Electives

<table>
<thead>
<tr>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>48–93</td>
</tr>
</tbody>
</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 and corequisites are listed in the subject description.
- A thesis of 12 units is required. Not more than 30 units of thesis credit may be included in the minimum of 180 units beyond the General Institute Requirements required for the SB degree.
- Subject descriptions identify subjects that cannot be used for this purpose.

For an explanation of credit units, or hours, please refer to the Subject Key in Part 3 of this Bulletin.
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 Gaithersberg, 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 characteristic 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 research 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, MIT 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 Inter-
national 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 4-315, 617-253-4841.

FACULTY AND STAFF
Faculty and Teaching Staff
Edmund W. Bertschinger, PhD
Professor of Physics
Department Head

Thomas John Greytak, PhD
Lester Wolfe Professor of Physics
Associate Head for Education

Professors
Raymond C. Ashoori, PhD
Professor of Physics
(On leave)

Ulrich Justus Becker, PhD
Professor of Physics

John Winston Belcher, PhD
Class of 22 Professor of Physics
MacVicar Faculty Fellow

George Bernard Benedek, PhD
Alfred H. Caspary Professor of Physics and Biological Physics

William Bertozzi, PhD
Professor of Physics

Wit Busza, PhD
Francis L. Friedman Professor of Physics

Claude Roger Canizares, PhD
Bruno Rossi Professor of Physics
Associate Director for MIT, Chandra X-ray Observatory Center
Vice President for Research and Associate Provost
Deepto Chakrabarty, PhD
Professor of Physics
Division Head, Astrophysics

Min Chen, PhD
Professor of Physics
Janet Conrad, PhD
Professor of Physics
Bruno Coppi, PhD
Professor of Physics

James Ludlow Elliot, PhD
Professor of Earth, Atmospheric and Planetary Sciences and Physics
Director, George R. Wallace, Jr. Astrophysical Observatory

Edward Henry Farhi, PhD
Cecil and Ida B. Green Career Development Professor of Physics
Director, Center for Theoretical Physics

Michael Stephen Feld, PhD
Professor of Physics
Director, George R. Harrison Spectroscopy Laboratory

Peter H. Fisher, PhD
Professor of Physics
Division Head, Particle and Nuclear Physics

Daniel Freedman, PhD
Professor of Mathematics and Physics

Alan Harvey Guth, PhD
Víctor F. Weisskopf Professor of Physics
MacVicar Faculty Fellow

Jacqueline N. Hewitt, PhD
Professor of Physics
Director, MIT Kavli Institute for Astrophysics and Space Research

Erich Peter Ippen, PhD
Elizur Thomson Professor of Electrical Engineering and Physics

Roman Wladimir Jackiw, PhD
Jerrold Zacharias Professor of Physics

Robert Jaffe, PhD
Professor of Physics
Otto and Jane Morningstar Professor of Science

John Dimitris Joannopoulos, PhD
Francis Wright Davis Professor of Physics
Director, Institute of Soldier Nanotechnologies

Paul Christopher Joss, PhD
Professor of Physics
(On leave, spring)

Mehran Kardar, PhD
Professor of Physics

Marc Aaron Kastner, PhD
Donner Professor of Science
Dean, School of Science

Wolfgang Ketterle, PhD
John D. MacArthur Professor of Physics
Director, MIT-Harvard Center for Ultracold Atoms

Stanley Benedict Kowalski, PhD
Professor of Physics

Patrick A. Lee, PhD
Professor of Physics

Walter Hendrik Gustav Lewin, PhD
Professor of Physics

J. David Litster, PhD
Professor of Physics

June Lorraine Matthews, PhD
Professor of Physics

Richard G. Milner, PhD
Professor of Physics
Director, Laboratory for Nuclear Science

Ernest J. Moniz, PhD
Professor of Physics
Director, Energy Studies

John William Negele, PhD
William A. Coolidge Professor of Physics

Miklos Porkolab, PhD
Professor of Physics
Director, Plasma Science and Fusion Center

David Edward Pritchard, PhD
Cecil and Ida B. Green Professor of Physics

Krishna Rajagopal, PhD
Professor of Physics

Saul Alan Rappaport, PhD
Professor of Physics
Robert Page Redwine, PhD  
Professor of Physics  
Director, Bates Laboratory  

Paul Schechter, PhD  
William A. M. Burden Professor of Astrophysics  

H. Sebastian Seung, PhD  
Professor of Computational Neuroscience and Physics  

Washington Taylor IV, PhD  
Professor of Physics  

Samuel C. C. Ting, PhD  
Thomas Dudley Cabot Professor of Physics  

Alexander van Oudenaarden, PhD  
Professor of Physics  
(On leave, fall)  

Xiao-Gang Wen, PhD  
Cecil and Ida Green Professor of Physics  

Frank Wilczek, PhD  
Herman Feshbach Professor of Physics  

Boleslaw Wyslouch, PhD  
Professor of Physics  

Eric Hudson, PhD  
Class of 1958 Career Development Associate Professor of Physics  

Jan Egedal-Pedersen, PhD  
Assistant Professor of Physics  

Enectali Figueroa-Feliciano, PhD  
Assistant Professor of Physics  

Joseph Formaggio, PhD  
Assistant Professor of Physics  
(On leave, fall)  

John McGrevey, PhD  
Assistant Professor of Physics  

Steven Nahn, PhD  
Assistant Professor of Physics  

Robert Simcoe, PhD  
Assistant Professor of Physics  
(On leave, spring)  

Marin Soljacic, PhD  
Assistant Professor of Physics  
(On leave, fall)  

Bernd Surrow, PhD  
Assistant Professor of Physics  

Joshua Winn, PhD  
Assistant Professor of Physics  
(On leave, spring)  

Martin Zwierlein, PhD  
Assistant Professor of Physics  

Nergis Mavalvala, PhD  
Cecil and Ida B. Green Associate Professor of Physics  
(On leave, fall)  

Leonid Mirny, PhD  
Associate Professor of Health Sciences and Technology and Physics  

Christoph M. E. Paus, PhD  
Associate Professor of Physics  

Gunther Roland, PhD  
Associate Professor of Physics  

Gabriella Sciola, PhD  
Cecil and Ida B. Green Career Development Associate Professor of Physics  

Sara Seager, PhD  
Ellen Swallow Richards Associate Professor of Earth, Atmospheric and Planetary Sciences and Physics  

Iain W. Stewart, PhD  
Associate Professor of Physics  
(On leave, fall)  

Max Tegmark, PhD  
Associate Professor of Physics  

Senthil Todadri, PhD  
Associate Professor of Physics  

Vladan Vuletic, PhD  
Lester Wolfe Associate Professor of Physics  

Alfred P. Sloan Research Fellow  

Associate Professors  
Isaac Chuang, PhD  
Associate Professor of Electrical and Engineering and Computer Science and Physics  

Eric Hudson, PhD  
Class of 1956 Career Development Associate Professor of Physics  

Scott Hughes, PhD  
Class of 1956 Career Development Associate Professor of Physics  

Erotokritos Katsavounidis, PhD  
Associate Professor of Physics  

Young Sang Lee, PhD  
Mark Hyman Jr. Career Development Associate Professor of Physics  

Hong Liu, PhD  
Assistant Professor of Physics  
(On leave, fall)  

John McGrevey, PhD  
Assistant Professor of Physics  

Steven Nahn, PhD  
Assistant Professor of Physics  

Robert Simcoe, PhD  
Assistant Professor of Physics  
(On leave, spring)  

Marin Soljacic, PhD  
Assistant Professor of Physics  
(On leave, fall)  

Bernd Surrow, PhD  
Assistant Professor of Physics  

Joshua Winn, PhD  
Assistant Professor of Physics  
(On leave, spring)  

Martin Zwierlein, PhD  
Assistant Professor of Physics  

Senior Lecturers  
Peter Dourmashkin, PhD  
Stephen Steadman, PhD  
George S. F. Stephans, PhD  

Lecturers  
David Kaiser, PhD  
Sean Robinson, PhD  
Scott Sewell, PhD  

Technical Instructors  
Andrew Neely, BS  
William Sanford, BS  
Eli Sidman, BS  

Research Staff  

Senior Research Scientists  
Thomas William Donnelly, PhD  
Earl S. Marmar, PhD  
Frank E. Taylor, PhD  
Richard J. Temkin, PhD  

Professors Emeriti  
Michel Baranger, PhD  
Professor of Physics, Emeritus  

Ahmet Nihat Berker, PhD  
Professor of Physics, Emeritus
Aron Myron Bernstein, PhD  
Professor of Physics, Emeritus  

George Fred Koster, PhD  
Professor of Physics, Emeritus  

Robert J. Birgeneau, PhD  
Professor of Physics, Emeritus  

Benjamin Lax, PhD  
Professor of Physics, Emeritus  

Hale Van Dorn Bradt, PhD  
Professor of Physics, Emeritus  

Earle Leonard Lomon, PhD  
Professor of Physics, Emeritus  

Bernard Flood Burke, PhD  
Professor of Physics, Emeritus  

Stanislav Olbert, PhD  
Professor of Physics, Emeritus  

George Whipple Clark, PhD  
Professor of Physics, Emeritus  

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Professor of Physics, Emeritus  

Eric Richard Cosman, PhD  
Professor of Physics, Emeritus  

Irwin Abraham Pless, PhD  
Professor of Physics, Emeritus  

Peter Theodore Demos, PhD  
Professor of Physics, Emeritus  

Lawrence Rosenson, PhD  
Professor of Physics, Emeritus  

Mildred Spiewak Dresselhaus, PhD  
Professor of Electrical Engineering and Physics  
Institute Professor, Emeritus  

Malcolm Woodrow Pershing Strandberg, PhD  
Professor of Physics, Emeritus  

George Fred Koster, PhD  
Professor of Physics, Emeritus  

Benjamin Lax, PhD  
Professor of Physics, Emeritus  

Benjamin Lax, PhD  
Professor of Physics, Emeritus  

Earle Leonard Lomon, PhD  
Professor of Physics, Emeritus  

Kerson Huang, PhD  
Professor of Physics, Emeritus  

Lawrence Rosenson, PhD  
Professor of Physics, Emeritus  

Karl Uno Ingard, PhD  
Professor of Aeronautics and Astronautics and  
Physics, Emeritus  

Peter Adalbert Wolff, PhD  
Professor of Physics, Emeritus  

Physics Industry Forum  

James Edward Young, PhD  
Professor of Physics, Emeritus  

Lee Grodzins, PhD  
Professor of Physics, Emeritus  

Laszlo Tisza, PhD  
Professor of Physics, Emeritus  

Kerson Huang, PhD  
Professor of Physics, Emeritus  

Rainer Weiss, PhD  
Professor of Physics, Emeritus  

Ali Javan, PhD  
Professor of Physics, Emeritus  

Peter Adalbert Wolff, PhD  
Professor of Physics, Emeritus  

Arthur Kent Kerman, PhD  
Professor of Physics  

Physics Industry Forum  

James Edward Young, PhD  
Professor of Physics, Emeritus  

John Gordon King, PhD  
Francis Friedman Professor of Physics, Emeritus  


Vera Kistiakowsky, PhD  
Professor of Physics, Emeritus  

Daniel Kleppner, PhD  
Lester Wolfe Professor of Physics, Emeritus  

James Edward Young, PhD  
Professor of Physics, Emeritus  

James Edward Young, PhD  
Professor of Physics, Emeritus
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<td>Harvard-MIT Division of Health Sciences and Technology</td>
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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 that provides students with a strong foundation in computational methods for the design and operation of complex engineered 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’s common core serves all engineering disciplines, and an elective component focuses on particular applications. The program emphasizes:

- Breadth through introductory courses in numerical analysis and simulation, and optimization
- 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

Participating faculty come from the schools of Engineering, Science, and Management, including the departments of Aeronautics and Astronautics, Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering and Computer Science, Mechanical Engineering, and Mathematics.

The research interests of CDO faculty cover a great variety of computationally intensive areas in engineering, science, and mathematics. Recent research has included such far-ranging topics as micromachined devices, guidance/control systems, imaging systems, distribution networks, telecommunications systems, and transportation systems. CDO faculty research encompasses applications in areas such as aircraft design, materials design, manufacturing operations scheduling, and applied optimization in operations and industrial engineering.

**Inquiries**

For further information about the CDO program, contact Laura Koller, Room 35-329, 617-253-3725, cdo_info@mit.edu; or visit [http://mit.edu/cdo-program/](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 Department of Biological Engineering. 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 305.

**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 307.

**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 307.

**Leaders for Manufacturing Program**

The Leaders for Manufacturing (LFM) program is an educational and research partnership among 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 in management or an 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 Engineering Systems Division or the MIT Sloan School of Management, or visit [http://lfm.mit.edu/](http://lfm.mit.edu/).

**Microbiology Program**

The Graduate Program in Microbiology—a new, interdepartmental, and interdisciplinary initiative at MIT—integrates educational resources across the participating departments to build connections among faculty with shared interests and to build an educational community for training students in the study of microbial systems.

This program provides a broad exposure to underlying elements of modern microbiological research and engineering as well as in-depth research experience in specific areas of microbiology. Program graduates will be prepared to work in a range of fields in microbial science and engineering, and will have excellent career options in academia, industry, and government.

See the full program description on page 316.

**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.


For further information, contact Laura Rose, Room E40-143, 617-253-9303, 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(s) of one of the following four
MIT departments: Chemical Engineering, Chemistry, Materials Science and Engineering, and/or Mechanical Engineering.

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 student’s home department.

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 successful 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, 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 technical professionals seeking to build upon their backgrounds and experience in order to 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 Engineering Systems Division 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.
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.

Computational and systems biology, as practiced at MIT, is organized around the “3 Ds”: description, distillation, and design. In many research programs, systematic data collection is carried out for the purpose of detailed molecular- or cellular-level description of a system. Given the complexity of biological systems and the number of interacting components and parameters, system modeling is usually conducted with the aim of distilling the essential or most important subsystems, components, and parameters, and of obtaining simplified models that retain the ability to accurately predict system behavior under a wide range of conditions. Distillation of the system ideally will increase interpretability of the models in relation to evolutionary and engineering principles such as robustness, modularity, evolvability. The resulting models may also serve to facilitate both rational design of perturbations to test understanding of the system or to change system behavior (e.g., for therapeutic intervention), as well as efforts to design related systems or systems composed of similar biological components.

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, instrumentation engineering, cell and tissue engineering, predictive toxicology and metabolic engineering, imaging and image informatics, 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 Department of Biological Engineering. 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 must have an undergraduate degree in biology (or a related field), computer science, mathematics, statistics, physics, or an engineering discipline, with dual-emphasis degrees encouraged.

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 semester 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, to prepare them for the complexities and demands of modern scientific research. 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 three 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 7.91j/20.490j Foundations of Computational and Systems Biology.

Topics in Computational and Systems Biology (One Subject): All first-year students in the program participate in CSB.100j/7.89j Topics in Computational and Systems Biology, an exploration of problems and approaches in the field of computational and systems biology through in-depth discussion and critical analysis.
of selected primary research papers. This subject is restricted to first-year PhD students in CSB or related fields 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 (Three Rotations):**
To assist students with lab selection and provide a range of research activities in computational and systems biology, students participate in three 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.

**FACULTY AND STAFF**

**CSB Graduate Committee**
Bruce Tidor, PhD
Professor of Biological Engineering and Computer Science

Chris Burge
Associate Professor of Biology
Chair of the Committee

Alan D. Grossman, PhD
Praecis Professor of Biology

Amy E. Keating, PhD
Sizer Career Development Associate Professor of Biology

Scott R. Manalis, PhD
Associate Professor of Biological and Mechanical Engineering

Joel Voldman, PhD
Associate Professor of Electrical Engineering

Forest White, PhD
Mitsui Associate Professor of Biological Engineering

Jacob K. White, PhD
Cecil H. Green Professor of Electrical Engineering
The Master of Health Sciences and Technology (MHST) is the oldest and largest health sciences program in the United States and the longest-standing collaboration between Harvard and MIT.

MHST’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 nine multidisciplinary options for graduate study:

1. Medical Sciences MD Program
2. Medical Engineering and Medical Physics Doctoral Program
3. Speech and Hearing Bioscience and Technology Doctoral Program
4. Radiological Sciences Joint Program
5. Biomedical Enterprise Master’s Program
6. Biomedical Informatics Training Program
7. Clinical Investigator Training Program
8. Master of Engineering in Biomedical Engineering
9. Graduate Education in Medical Sciences Certificate Program

**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. Further information is available at [http://bep.mit.edu/](http://bep.mit.edu/) or by contacting bep@mit.edu.

**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 Academic Office, Room E25-518, 617-258-7084.
DOCTORAL PROGRAMS

Medical Engineering and Medical Physics

The Medical Engineering and Medical Physics (MEMP) Program is a five-to-seven–year program that leads to the PhD in Medical Engineering and Medical Physics awarded by MIT or by the Harvard Faculty of Arts and Sciences. The program trains students as engineers or physical scientists who also have extensive knowledge of the medical sciences. By understanding engineering and physical science applications, as well as their clinical implications, graduates of this program are well positioned to define new questions and formulate novel approaches in biomedical research.

The MEMP program is founded on a philosophy of openness and collaboration, characteristics that encourage innovative and independent thinking and creativity. This philosophy is fostered by the unique environment in which MEMP students study. While each MEMP student has depth in one classical discipline of engineering or physical science, the collective community has students in all disciplines. MEMP students also have peers with diverse career paths in medicine, science, engineering, business, and government. This community promotes an open exchange of ideas and exposes students to different perspectives on the health sciences. Moreover, MEMP students have access to research opportunities in labs at Harvard, MIT, and the Harvard teaching hospitals. Students can do research with faculty at any of these institutions and have many opportunities through classes, events, and projects to interact with faculty from all of these institutions.

The program’s academic curriculum includes three phases that prepare students to be medical innovators who will advance human health. First, HST provides MEMP students with a thorough graduate education in a classical discipline of engineering or physical science. Each student selects a concentration area, such as mechanical engineering, chemistry and chemical engineering, materials science, electrical engineering, computer science, physics, aeronautics and astronautics, or nuclear engineering, and completes substantial coursework in this discipline.

Students then become conversant in the biological sciences through preclinical coursework followed by a series of clinical experiences. They acquire a hands-on understanding of clinical care, medical decision-making, and the role of technology in medical practice both in the classroom and in patient care. Because the interface of technology and clinical medicine represents a continuum that extends from the molecular to the whole-organism levels, MEMP offers two distinct but related curricular sequences in the biomedical sciences: the cellular and molecular medicine sequence and the systems physiology and medicine sequence.

Finally, MEMP students investigate important problems at the interfaces of science, technology, and clinical medicine through individualized research projects that prepare them to undertake independent research. MEMP students have the opportunity to perform thesis research in laboratories at MIT, Harvard, and the Harvard affiliated teaching hospitals.

Bioinformatics and integrative genomics (BIG), neuroimaging and bioastronautics are areas of specialization within MEMP for which HST offers specially designed training programs. MEMP candidates may choose to apply through MIT, Harvard, or both. Those applying to MEMP through MIT should submit a single application. Those applying to MEMP through Harvard must also apply to the School of Engineering and Applied Sciences or the Biophysics Program. Additional information about applying to MEMP is available at http://hst.mit.edu/public/admissions/.

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, 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 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 Nuclear Science and Engineering Department and Boston-area teaching hospitals. Students complete a doctoral program in nuclear science and engineering in addition to a focused clinical experience that includes basic biomedical courses and a clinical practicum. Training is provided in ionizing and non-ionizing radiation systems engineering and applications to biological and biomedical issues. This is accomplished through an academic core of nuclear physics and radiation engineering supplemented by biomedical subjects and a focused clinical experience. Student research topics typically involve radiation therapy or imaging, such as magnetic resonance imaging (MRI), computer-aided tomography (CT), positron emission tomography (PET), or single-photon emission tomography (SPECT). Recent innovations in the areas of particle radiation therapy and medical imaging have made this area one of the most exciting in the field of applied nuclear and radiation science.

The core curriculum includes topics in nuclear and radiation physics, radiation biology, medical imaging, and the biomedical application of radiation. These subjects form the basis of the departmental doctoral examination taken by most students two years after entering the program. After successful completion of the exam, full-time thesis research is pursued in specialty areas of radiation therapy, medical imaging, radiation biology, and biophysics, or image processing and computer applications. 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 a doctoral thesis and defend it before a committee of MIT faculty, including members from HST and the Department of Nuclear Science and Engineering, in accordance with the interdisciplinary nature of the program.

Admission to the RSJP program is decided jointly by HST and MIT's Department of Nuclear Science and Engineering. In addition to a strong background in the physical and engineering sciences, applicants should have completed two undergraduate subjects in biology or biochemistry before entering RSJP. Additional information may be obtained by contacting Clare Egan, Room 24-102, 617-253-3814, cegan@mit.edu.

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 five-to-seven-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, as well as 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 communication 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 and physiological 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 at http://web.mit.edu/shbt/ or 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.
TRAINING PROGRAMS

In addition to the specialized training programs designed as tracks within the Medical Engineering Medical Physics Doctoral Program, described above, HST offers three training programs in specific areas.

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 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 individuals who have already 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, visit http://www.mi-boston.org/Boston-Informatics/index.html or contact Dr. Lucila Ohno-Machado, Decision Systems Group, Brigham and Women’s Hospital, 75 Francis Street, Boston, MA 02115, machado@ds.g.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, in vitro 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, visit http://www.bidmc.harvard.edu/citp/ or contact the CITP administrative manager, Linda Bard, Beth Israel Deaconess Medical Center, 330 Brookline Ave, GZ 811, Boston, MA 02215, lbard@bidmc.harvard.edu.

Graduate Education in Medical Sciences Certificate Program

The MIT Graduate Education in Medical Sciences (GEMS) Training Program is a part-time certificate program that can be taken concurrently with doctoral studies and research by students in the Schools of Engineering and Science to gain exposure to biomedical and clinical sciences, including translational medicine. This educational experience for PhD graduate students in the sciences and engineering fields addresses a national need articulated by the Howard Hughes Medical Institute: the growing gap between advances in basic biology and the translation of those advances into medically relevant therapies and tools for the improvement of human health.

The GEMS training program aims to integrate medical knowledge into graduate education at MIT by training a select group of PhD students to bridge the widening chasm between concept and functional execution with a supplementary curriculum that entails: (1) a human pathology course, including molecular and cellular mechanisms of disease, (2) a medical pathophysiology course, a kaleidoscope of HST’s pathophysiology curriculum, (3) a student-individualized clinical experience, working with experienced mentors who move seamlessly between clinical medicine and basic biological research, (4) a seminar showcasing examples of translation, and (5) HST’s Graduate Seminar—attended by all HST PhD candidates—focusing on professional skills needed to succeed in interdisciplinary research (ethics, responsible conduct of research, communication, etc.). GEMS participants will gain an understanding of the elements of translation, appreciate the science and art of medicine in a way that cannot be conveyed by textbooks, and develop relationships with students and faculty in the broad biomedical community.

Inquiries

Additional information on degree programs, admissions, and financial aid can be obtained from HST’s Academic Office, Room E25-518, 617-492-4091.
FACULTY AND STAFF

Faculty and Teaching Staff
Martha L. Gray, PhD
Edward Hood Taplin Professor of Medical and Electrical Engineering, MIT
Director

David E. Cohen, MD, PhD
Associate Professor of Medicine and Health Sciences and Technology, HMS, BWH
Director

Lee Gehrke, PhD
Hermann von Helmholtz Professor of Health Sciences and Technology, MIT, HMS
Professor of Microbiology and Molecular Genetics, HMS
Associate Director for Faculty

Richard N. Mitchell, MD, PhD
Associate Professor of Pathology and Health Sciences and Technology, HMS, BWH
Associate Master for MD Program

Professors
R. Rox Anderson, MD
Professor of Dermatology and Health Sciences and Technology, HMS, MGH

George B. Benedek, PhD
Alfred H. Caspary Professor of Physics and Biological Physics and Health Sciences and Technology, MIT

Sangeeta N. Bhatia, MD, PhD
Professor of Health Sciences and Technology and of Electrical Engineering and Computer Science, MIT

Howard Hughes Medical Institute Investigator

Joseph V. Bonventre, MD, PhD
Robert H. Ebert Professor of Medicine and Health Sciences and Technology, HMS, BWH

Louis D. Braid, PhD
Henry Ellis Warren Professor of Electrical Engineering and Health Sciences and Technology, MIT

Emery N. Brown, MD, PhD
Professor of Health Sciences and Technology and of Computational Neuroscience, MIT

Thomas N. Byrne, MD
Clinical Professor of Neurology and Health Sciences and Technology, HMS, MGH

Richard J. Cohen, MD, PhD
Whitaker Professor in Biomedical Engineering, MIT

Ernest G. Cravalho, PhD
Professor of Mechanical Engineering and Health Sciences and Technology, MIT

Elazer R. Edelman, MD, PhD
Thomas D. and Virginia W. Cabot Professor of Health Sciences and Technology, MIT

Dennis M. Freeman, PhD
Professor of Electrical Engineering, MIT

John D. E. Gabrieli, PhD
Grover Hermann Professor of Health Sciences and Technology and Professor of Brain and Cognitive Sciences, MIT

David E. Housman, PhD
Ludwig Professor of Biology, MIT

Robert D. Howe, PhD
Gordon McKay Professor of Engineering, Harvard University

Isaac S. Kohane, MD, PhD
Lawrence J. Henderson Professor of Pediatrics and Health Sciences and Technology, HMS, CHB

Robert S. Langer Jr., ScD
Institute Professor

M. Charles Liberman, PhD
Professor of Otolaryngology and Health Sciences and Technology, MIT, MEEI

Roger G. Mark, MD, PhD
Distinguished Professor in Health Sciences and Technology and Electrical Engineering and Computer Science, MIT

Bruce R. Rosen, MD, PhD
Professor of Radiology and Health Sciences and Technology, HMS, MGH

John J. Rosowski, PhD
Professor of Otolaryngology and Health Sciences and Technology, HMS, MEEI

Robert H. Rubin, MD
Gordon and Marjorie Osborne Professor of Health Sciences and Technology, HMS, HST
Professor of Medicine, HMS, BWH

Ram Sasisekharan, PhD
Professor of Biological Engineering and Health Sciences and Technology, MIT

Frederick J. Schoen, MD, PhD
Professor of Pathology and Health Sciences and Technology, HMS, BWH

Brian Seed, PhD
Professor of Genetics and Health Sciences and Technology, HMS, MGH

Daniel C. Shannon, MD
Professor of Pediatrics and Health Sciences and Technology, HMS, MGH

Anthony J. Sinskey, ScD
Professor of Biology and Health Sciences and Technology, MIT

Peter Szolovits, PhD
Professor of Computer Science and Engineering and Health Sciences and Technology, MIT

Mehmet Toner, PhD
Professor of Surgery and Health Sciences and Technology, HMS, MGH

Richard J. Wurtman, MD
Cecil H. Green Distinguished Professor of Neuropharmacology and Health Sciences and Technology, MIT

Martin L. Yarmush, MD, PhD
Helen Andrus Benedict Professor of Surgery (Biological Chemistry and Molecular Pharmacology), HMS, MGH

Laurence R. Young, ScD
Apollo Program Professor of Astronautics and Health Sciences and Technology, MIT

Associate Professors
Elfar Adalsteinsson, PhD
Associate Professor of Health Sciences and Technology and of Electrical Engineering and Computer Science, MIT

Brett Bouma, PhD
Associate Professor of Dermatology and Health Sciences and Technology, HMS, MGH

M. Christian Brown, PhD
Associate Professor of Otolaryngology and Health Sciences and Technology, HMS, MEEI
Martha Bulyk, PhD
Associate Professor of Medicine and Health Sciences and Technology, HMS, BWH

Deborah Burstein, PhD
Associate Professor of Radiology and Health Sciences and Technology, HMS, BIDMC

W. H. Churchill Jr., MD
Associate Professor of Medicine and Health Sciences and Technology, HMS, BWH

Bertrand Delgutte, PhD
Associate Professor of Otology and Laryngology and Health Sciences and Technology, HMS, MEEI

Donald K. Eddington, PhD
Associate Professor of Otology and Laryngology and Health Sciences and Technology, HMS, MEEI

John J. Guinan, Jr., PhD
Associate Professor of Otology and Laryngology, HMS, MEEI

Hugh M. Herr, PhD
Associate Professor in Media Arts and Sciences, and Health Sciences and Technology, MIT

Robert E. Hillman, PhD
Associate Professor of Surgery and Health Sciences and Technology, HMS, MGH

Lucila Ohno-Machado, MD, PhD
Associate Professor of Radiology and Health Sciences and Technology, HMS, BWH

Lee H. Schwamm, MD
Associate Professor of Neurology, HMS, MGH

Leonid A. Mirny, PhD
Samuel A. Goldblith Career Development Associate Professor of Health Sciences and Technology and Physics, MIT

Senior Lecturers
Stephen K. Burns, PhD
Teodoro F. Dagi, MD
Howard L. Golub, MD, PhD
Stanley N. Lapidus

Lecturers
Laurence I. Alpert, MD
Jeffrey S. Behrens, MS, MBA
Carl M. Berke, PhD
Jeffrey Blander, ScD
Jonathan P. Gertler, MD
Linda C. Hemphill, MD
Jacob Joseph, MD
Susanne Klingenstein, PhD
J. Christian Kryder, MD
Steven M. Lulich, PhD
Robert P. Marini, DVM
Timothy A. Wagner, PhD

Research Staff
Senior Research Scientist
Stan N. Finkelstein, MD
James C. Weaver, PhD

Principal Research Scientists
Jane-Jane Chen, PhD
Gari D. Clifford, PhD
Lisa E. Freed, MD, PhD
Julie E. Greenberg, PhD
Chi-Sang Poon, PhD
Simona Socrate, PhD

Research Scientists
Mercedes Balcells-Camps, PhD
T. R. Gowrishankar, PhD
Kichang Lee, PhD
Glover W. Martin, PhD
Gang Song, PhD
Gregory H. Underhill, PhD

Research Engineers
Michelle L. Farley
Li-Wei H. Lehman, PhD
George B. Moody

Research Associate
Ann M. Lees, MD

Research Fellows
Gil Alterovitz, PhD
David A. Harmon, MD
Michael Jernigan, MD
Ronilda C. Lacson, MD
Elizabeth L. Scheufele, MD

Postdoctoral Associates
Amit Agrawal, PhD
Natalie Artzi, PhD
Edwin Pak-Nin Chan, PhD
Aaron M. Dollar, PhD
Paula L. Feinberg-Zadek, PhD
Smuel Hess, PhD
Elliot E. Hui, PhD
Salman R. Khetani, PhD
Vijaya B. Kolachalama, PhD
Li Yuan Mi, PhD
Neetu Singh, PhD
Evgeny Ter-Ovanesyan, PhD
A. Rami Tzafriri, PhD
Piia K. Valonen, PhD
David K. Wood, PhD
Brett G. Zani, PhD

Postdoctoral Fellows
Jeremy Slade Abramson, MD
Rajendra D. Badgaiyan, MD
Aaron B. Baker, PhD
Stephan B. Danik, MD
George C. Engelmayr, PhD
Elizabeth A. Hoge, MD
Steven Jay Isakoff, MD, PhD
Sandra March-Riera, PhD
Jason W. Nichol, PhD
N. V. S. Rajasekhar Suragani, PhD

Technical Assistants
Stephen M. Katz, BA
Emma-Kate Loveday, BS
Michele P. Miele, BS
Wanting Zhao, BA

Visiting Engineer
Mauricio C. Villarroel Montoya

Visiting Scientists
Robert G. Dennis, PhD
Yingle Fan, PhD
Pedro E. Huertas, MD, PhD
Luismar Marques Porto, PhD
Andrew T. Reisner, MD
Igor B. Rozenvald, MD
Viswanathan Sasishekaran, PhD
Rajesh V. Swaminathan, MD
Gordana V. Vunjak-Novakovic, PhD
Sang Hoon Yi, PhD
Stephen E. Zale, PhD

Visiting Scholars
Iram Amjad, MSc
Dina Uzri, BS

Professors Emeriti
Walter H. Abelmann, MD
Professor of Medicine, Emeritus, HMS
Director, Alumni Affairs

Robert S. Lees, MD
Professor of Health Sciences and Technology, Emeritus, MIT

Irving M. London, MD
Professor of Medicine, Emeritus, HMS
Professor of Biology, Emeritus, MIT

Kenneth N. Stevens, ScD
Clarence J. Lebel Professor of Electrical Engineering and Health Sciences and Technology, Emeritus, MIT
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 videoconferencing system between MIT and Woods Hole provides interactive transmission for classes, meetings, and other joint events. 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.

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, paleoceanography, gravity, magnetics, heat flow, sediment dynamics, and isotope geology. 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.

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.
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 Graduate Admissions Office 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, 617-253-7544. More information is available online at http://web.mit.edu/mit-whoi/www/.
The study of microbes has been critical in our current understanding of basic biological processes, evolution, and the functions of the biosphere, and has contributed to numerous fields of engineering. Microbes have the amazing ability to grow in extreme conditions, to grow slowly or rapidly, and to readily exchange DNA. They are essential for life as we know it, but can also be agents of disease. They are instrumental in shaping the environment, in evolution, and in modern biotechnology. Microbes are amenable to virtually all modern approaches in science and engineering. As such, they provide natural engineering laboratories for creating new capabilities for industry (e.g., pharmaceuticals, chemicals, energy) and are the foundation of pioneering efforts in synthetic biology, i.e., building life from its component parts. Effective study of microbes and their applications demands multiple interdisciplinary approaches that cross all scales of biological organization, from molecules to vast ecosystems.

Research in microbiology is being conducted throughout MIT by more than 50 faculty from departments in both the Schools of Science and the School of Engineering, including Biology; Biological Engineering; Chemical Engineering; Chemistry; Civil and Environmental Engineering; Earth, Atmospheric, and Planetary Sciences; Electrical Engineering and Computer Science; Materials Sciences and Engineering; and Physics. Many labs take multiple approaches to studying and manipulating microbial systems and the expertise and research covers a wide range of areas, including biochemistry, genetics, structural biology, genomics, systems biology, computational biology, chemical and biological engineering, biotechnology, synthetic biology, cell and molecular biology, ecology, evolutionary biology, pathogenesis, geobiology and environmental biology.

The Graduate Program in Microbiology—a new, interdepartmental, and interdisciplinary initiative at MIT—integrates educational resources across the participating departments to build connections among faculty with shared interests and to build an educational community for training students in the study of microbial systems.

Interdisciplinary training in microbiology is in increasing demand in both public and private sectors. This program provides a broad exposure to underlying elements of modern microbiological research and engineering as well as in-depth research experience in specific areas of microbiology. Program graduates will be prepared to work in a range of fields in microbial science and engineering, and will have excellent career options in academia, industry, and government.

## CURRICULUM

The major components of the training program are required course work; elective course work; rotations and thesis research; teaching; training in the ethical conduct of research; and qualifying exams.

### Required Subjects

- 7.492J Methods and Problems in Microbiology
- 7.493J Microbial Genetics and Evolution
- 7.499 Research Rotations in Microbiology
- 7.57 Quantitative Biology of Molecular Systems

**One of the following biochemistry subjects:**

- 7.51 Principles of Biochemical Analysis
- 5.08J Biological Chemistry II

### Elective Subjects

Students must take three elective subjects, totaling 36 units, from the following list. Electives can be chosen to provide depth in a specific area of interest or additional breadth in training. Subjects from some other areas may also fulfill the requirement, with the approval of the Graduate Education committee.

- 1.89 Environmental Microbiology
- 5.062 Principles of Bioinorganic Chemistry
- 5.451 Chemistry of Biomolecules and Natural Product Pathways
- 5.50 Enzymes: Structure and Function
- 5.52 Advanced Biological Chemistry
- 5.55 Chemical Tools for Assessing Biological Function
- 5.64 Biophysical Chemistry
- 5.65 Molecular Imaging
- 5.78 Biophysical Chemistry Techniques
- 6.874 Computational Systems Biology
- 7.21 Microbial Physiology
- 7.56 Foundations of Cell Biology
- 7.58 Molecular Biology
- 7.63 Immunology
- 7.70 Regulation of Gene Expression
- 7.75J Topics in Metabolic Biochemistry
- 7.91J Foundations of Computational and Systems Biology
- 8.59J Systems Biology
- 10.54 Biochemical Engineering
- 10.544 Metabolic and Cell Engineering
- 5.70J Statistical Thermodynamics with Applications to Biological Systems
- 10.977 Advances in Bioinformatics and Metabolic Engineering
- 20.106J Systems Microbiology
- 20.440 Analysis of Biological Networks
- 20.450 Molecular and Cellular Pathophysiology
- 20.485 Tools for Assessing Biological Function
- HST.508 Quantitative Genomics

### Rotations and Thesis Research

During the first year, students will rotate through three labs of MIT faculty that participate in the Microbiology Graduate Program. These rotations will help provide students broad exposure to microbiology research and will be used to select a lab for their thesis research by the end of the first year. Given the interdisciplinary nature of the program and many research programs, students may be able to work jointly with more than one research supervisor.

### Teaching Experience

Learning to effectively communicate scientific ideas is an important skill. Students in the Microbiology program will have an opportunity to improve their communication skills through teaching. Each student will serve as a teaching assistant for one term in an undergraduate or graduate subject related to microbiology. This will typically take place in the second year.

### Training in Ethical Conduct

All students will participate in a course on the ethical conduct of research. This will typically take place during the first year.
Qualifying Exams. Students will proceed to PhD candidacy after successful completion of a qualifying exam, typically during the second year. Students will submit a written research proposal in the style of a grant or fellowship application based on their planned thesis project. Students will then present and discuss the research proposal with a small committee of faculty.

FINANCIAL SUPPORT AND FELLOWSHIPS

Students in the program will be financially supported throughout their training. This support includes tuition, stipend, and health insurance. All students in the program will receive a stipend that is sufficient to support living in the Cambridge/Boston area. The stipend will be approximately the same as for graduate students in other MIT departments, approximately $29,000 in 2008–2009.

During the first year, students are supported by funds from the Provost’s Office, the School of Science, and the Departments of Biological Engineering, Biology, Chemical Engineering, and Chemistry. In subsequent years, students will be supported as research assistants in their thesis lab. Although students will be supported, they are strongly encouraged to apply for fellowships.

INQUIRIES

For further information about the Graduate Program in Microbiology, contact Bonnie Lee Whang, Room 68-139, microbiology@mit.edu, or visit http://microbiology.mit.edu/.