DEPARTMENT OF MECHANICAL ENGINEERING

Mechanical engineering is concerned with the responsible development of products, processes, and power, at scales ranging from molecules to large and complex systems. Mechanical engineering principles and skills are involved 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 of Mechanical Engineering (MechE), one that has widened rapidly in the past decade. Today, our faculty are involved in a wide range of projects, including designing tough hydrogels, using nanostructured surfaces for clean water and thermal management of microelectronics, developing efficient methods for robust design, the building of robotics for land and underwater exploration, creating optimization methods that autonomously generate decision-making strategies, developing driverless cars, inventing cost-effective photovoltaic cells, developing thermal and electrical energy storage systems, using acoustics to explore the ocean of one of Jupiter's moons, studying the biomimetics of swimming fish for underwater sensing applications, developing physiological models for metastatic cancers, inventing novel medical devices, exploring 3D printing of nanostructures and macrostructures, and developing coatings to create nonstick surfaces.

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 necessary for predicting thermo-mechanical phenomena and using 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 and transport
- 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. Design, manufacturing, and product development is the complete set of activities needed to bring new devices and technologies to the marketplace. These activities span the entire product life-cycle, from the identification of a market opportunity or need, through design, testing, manufacture and distribution, and end of useful life. Our work includes everything from understanding the voice of the customer to finding new ways of processing materials to improving product performance and tracking product flow through a distribution network. A central component of this area is the design and construction of novel equipment, either for consumer products or for industrial uses. This spans scales from meters to microns, and involves mechanical, electronic and electromechanical devices. Many MechE students apply design, manufacturing, and product development skills and techniques to extracurricular design work for organizations and student activities such as Design that Matters, Formula SAE, Satellite Engineering Team, and the Solar Electric Vehicle Team. Some projects lead to flagship products for new companies. A Course 2-A track in product development is offered along with a unique Master of Engineering degree in manufacturing.

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, medical and security related imaging, space and ocean exploration, and autonomous systems in air, land, and underwater environments. 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 fundamental 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; thermoelectric energy conversion; low- and high-temperature fuel cells; and novel materials for rechargeable batteries and thermal energy storage. 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 understanding for the development of novel ocean systems studying marine animals; the study of the mechanics and fluid mechanics of systems for ultradeep ocean gas and oil extraction; ocean wave and offshore wind energy extraction; the free surface hydrodynamics of ocean-going vehicles; the development of advanced naval and commercial ships and submersibles, including the all-electric ship; the mechanics and crashworthiness of ocean ships and structures; ocean transportation systems; ocean acoustics for communication, detection, and mapping in the ocean; and adaptive sampling and multidisciplinary forecasting of the ocean behavior. The design of complex ocean systems permeates all these areas and provides the cohesive link for our research and teaching activities.

Area 6: Bioengineering. Engineering analysis, design, and synthesis are needed to understand biological processes and to harness them successfully for human use. Mechanical forces and structures play an essential role in governing the function of cells, tissues, and organs. Our research emphasizes integration of molecular-to-systems–level approaches to probe the behavior of natural biological systems, and to design and build new systems, ranging from analysis of gene regulatory networks to microfluidic assays for drug screening or new technologies for quantitative, high-throughput biomedical imaging. Emphasis is also placed on creating new physiological or disease models, including multicellular engineered living systems, using nano- and micro-fabrication as well as new biomaterials. Applications include understanding, diagnosing, and treating diseases such as atherosclerosis, osteoarthritis, spinal cord injury or 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 at the undergraduate and graduate levels, 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 products that are already deployed as automobile airbag sensors, smart phone parts, and for drug delivery; stronger and lighter nanostructured materials now used in airplanes and automobiles; and nanostructured energy conversion devices that significantly improve the efficiency of renewable energy systems. Research in this area cuts across mechanical engineering and other disciplines. Examples include sensors and actuators; micro-fluidics, heat transfer, and energy conversion at the micro- and nanoscales; optical and biological micro- and nano-electromechanical systems (MEMS and NEMS); engineered nanomaterials; atomic scale precision engineering; and the nano-phoptonics in measurement, sensing, and systems design. Students interested in micro/nano technology are encouraged to explore the Course 2-A nanoengineering 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 (MechE) 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 (*https://catalog.mit.edu/degree-charts/mechanical-engineering-course-2*) are that:

Within a few years of graduation, a majority of our graduates will have completed or be progressing through top graduate programs; advancing in leadership tracks in industry, non-profit organizations, or the public sector; or pursuing entrepreneurial ventures. In these roles they will: (1) apply a deep working knowledge or technical fundamentals in areas related to mechanical, electromechanical, and thermal systems to address needs of the customer and society; (2) develop innovative technologies and find solutions to engineering problems; (3) communicate effectively as members of multidisciplinary teams; (4) be sensitive to professional and societal contexts and committed to ethical action; (5) lead in the conception, design, and implementation of new products, processes, services, and systems.

Students are urged to contact the MechE Undergraduate Office as soon as they have decided to enter mechanical engineering so that a faculty advisor may be assigned. Students, together with their faculty advisors, plan a program that best utilizes the departmental electives and the 48 units of unrestricted electives available in the Course 2 degree program.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET) (*http://www.abet.org*) as a mechanical engineering degree.

Bachelor of Science in 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 topics 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.

This program is accredited by the Engineering Accreditation Commission of ABET as an engineering degree.

The educational objectives of the program leading to the degree of Bachelor of Science in Engineering (*https://catalog.mit.edu/degree-charts/mechanical-engineering-course-2-a*) are that:

Within a few years of graduation, a majority of our graduates will have completed or be progressing through top graduate programs; advancing in leadership tracks in industry, non-profit organizations, or the public sector; or pursuing entrepreneurial ventures. In these roles they will: (1) apply a deep working knowledge or technical fundamentals in areas related to mechanical, electromechanical, and thermal systems to address needs of the customer and society; (2) develop innovative technologies and find solutions to engineering problems; (3) communicate effectively as members of multidisciplinary teams; (4) be sensitive to professional and societal contexts and committed to ethical action; (5) lead in the conception, design, and implementation of new products, processes, services, and systems.

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 robotics, engineering management, product development, biomedical engineering and pre-medicine, energy conversion engineering, sustainable development, architecture and building technology, and any of the seven departmental focus areas mentioned above. The MechE faculty have developed specific recommendations in some of these areas; details are available from the MechE 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 (150 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 72 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 concentration subjects to the particular theme of the concentration must be obvious.

To pursue the 2-A degree, students must submit the online 2-A enrollment form no later than Add Date of their second term in the program.

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 subjects, 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 program is accredited by the Engineering Accreditation Commission of ABET 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 (*https://catalog.mit.edu/degree-charts/mechanical-ocean-engineering-course-2-oe*) are that within a few years of graduation, a majority of our graduates will have completed or be progressing through top graduate programs; advancing in leadership tracks in industry, non-profit organizations, or the public sector; or pursuing entrepreneurial ventures. In these roles they will: (1) apply a deep working knowledge or technical fundamentals in areas related to mechanical, electromechanical, and thermal systems to address needs of the customer and society; (2) develop innovative technologies and find solutions to engineering problems; (3) communicate effectively as members of multidisciplinary teams; (4) be sensitive to professional and societal contexts and committed to ethical action; (5) lead in the conception, design, and implementation of new products, processes, services, and systems.

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

Minor in Mechanical Engineering

Students pursuing a minor in the department must complete a total of six 12-unit subjects in the Mechanical Engineering Department program. At least three of the subjects must be selected from among the required subjects for the Course 2 and Course 2-OE degree programs, which are listed below. In addition, two subjects may be selected from restricted electives in those programs.

18.03	Differential Equations [1]	12
Select three of the following:		36
2.001	Mechanics and Materials I	
2.002	Mechanics and Materials II	
2.003[J]	Dynamics and Control I	
2.004	Dynamics and Control II	
2.005	Thermal-Fluids Engineering I	
2.006	Thermal-Fluids Engineering II	
2.007	Design and Manufacturing I	
2.008	Design and Manufacturing II	
2.009	The Product Engineering Process	
2.017[J]	Design of Electromechanical Robotic Systems	
2.019	Design of Ocean Systems	
2.612	Marine Power and Propulsion	
2.086	Numerical Computation for Mechanical Engineers	
2.671	Measurement and Instrumentation	
Select two additional subjects from the required subjects or restricted electives for either Course 2 or Course 2-OE [2]		24
Total Units		**72**

1 *18.032 Differential Equations is also an acceptable option. Consult department for other alternatives.*

2 *For information about restricted electives in these programs, please refer to the department's website (http://meche.mit.edu/academic/undergraduate/mecheminor).*

Inquiries

Further information on undergraduate programs may be obtained from the MechE Undergraduate Office (*me-undergradoffice@mit.edu*), Room 1-110, 617-253-230.

Graduate Study

The Department of Mechanical Engineering (MechE) provides opportunities for graduate work leading to the following degrees: Master of Science in Mechanical Engineering, Master of Science in Ocean Engineering, Master of Science in Naval Architecture and Marine Engineering, Master of Science in Oceanographic 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 in Manufacturing degree is a 12-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.

Admission Requirements for Graduate Study

Applications to the mechanical engineering graduate program are accepted from persons who have completed, or will have completed by the time they arrive, a bachelor's degree if they are applying for a master's degree, or a master's degree if they are applying for a PhD. 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.

Applications for September entry are due on December 15 of the previous year and decisions are reported in March. International 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. International students whose native language is not English are required to take either the International English Language Testing System (IELTS) exam and receive a minimum score of 7 or the TOEFL exam with a minimum acceptable score of 577 (PBT), 233 (CBT) or 100 (iBT).

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 advise 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 international, must take the departmental writing ability test, which is administered online in June. Depending on the results, a student will either pass or be required to take a short course during the Independent Activities Period (IAP) (*https://catalog.mit.edu/mit/undergraduate-education/academic-research-options/independent-activities-period*) in January.

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 subjects (refer to the Guide to Graduate Study [PDF] (*http://meche.mit.edu/documents/MechE_Grad_Guide.pdf*) on the MechE website). The remainder of the 72 units may include advanced undergraduate subjects that are not requirements in the undergraduate mechanical engineering curriculum.

At least three of the graduate subjects must be taken in mechanical engineering sciences (refer to the Guide to Graduate Study [PDF] (*http://meche.mit.edu/documents/MechE_Grad_Guide.pdf*) on the MechE website). Students must take at least one graduate mathematics subject (12 units) offered by the MIT Mathematics Department. For the Master of Science in Oceanographic Engineering, see also the requirements listed in the Joint Program with Woods Hole Oceanographic Institution.

Finally, a thesis is required. The thesis is an original work of research, development, or design, performed under the advisement 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/Master of Science in Oceanographic Engineering

The requirements for each of these three degrees are that the student takes 72 credit units of graduate subjects and complete a thesis.

At least three of the subjects must be chosen from a prescribed list of ocean engineering subjects (refer to the Guide to Graduate Study [PDF] (*http://meche.mit.edu/documents/MechE_Grad_Guide.pdf*) on the MechE website). Students must also take at least one graduate mathematics subject (12 units) offered by MIT's Mathematics Department. For the Master of Science in Oceanographic Engineering, see also the requirements listed under the Joint Program with Woods Hole Oceanographic Institution.

The required thesis is an original work of research, development, or design, conducted under the advisement of a faculty or senior research staff member. The thesis usually takes between one and two years to complete.

Master of Engineering in Advanced Manufacturing and Design

The Master of Engineering in Advanced Manufacturing and Design (*http://web.mit.edu/meng-manufacturing*) is a 12-month professional degree in mechanical engineering that is intended to prepare the student to assume a role of technical leadership in the manufacturing industries. The degree is aimed at practitioners who will use this knowledge to become leaders in existing, as well emerging, manufacturing companies. To qualify for this degree, a student must complete a highly integrated set of subjects and projects that cover the process, product, system, and business aspects of manufacturing, totaling 90 units, plus complete a group-based thesis project with a manufacturing industry. While centered in engineering and firmly grounded in the engineering sciences, this degree program considers the entire 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 two additional essay questions are required.

Learners who earn an MITx Principles of Manufacturing MicroMasters Credential (*https://www.edx.org/micromasters/mitx-principles-manufacturing*) may apply to the Advanced Manufacturing and Design program and, upon acceptance, would be credited 48 units of advanced standing credit (equivalent to approximately one-third of the full degree program and one semester on campus).

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 a Mechanical Engineering examination and 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 Naval Construction and Engineering (NVE) 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 education for a career as a naval engineer.

The program leads to the Naval Engineer's degree, which requires a higher level of professional competence and broader range of knowledge than is required for the degree of Master of Science in Naval Architecture and Marine Engineering or Ocean Engineering. Subjects in the areas of economics, industrial management, and public policy and law, and at least 12 units of comprehensive design are required, in addition to an in-depth curriculum that includes naval architecture, hydrodynamics, ship structures, materials science, and power and propulsion. The program is appropriate for naval officers and civilians who plan to participate in the design and construction of naval ships, as well as those interested in commercial ship design.

For students working toward a simultaneous Naval Engineer's degree and a master's degree, a single thesis is generally acceptable, provided it is appropriate to the specifications of both degrees, demonstrating an educational maturity expected of the Naval Engineer's degree.

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 MechE 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 makes a final recommendation for a public defense of the work. The doctoral program typically requires three years of work beyond the master's degree, although this time is strongly topic dependent.

Interdisciplinary Programs

Graduate students registered in the Department of Mechanical Engineering may elect to participate in interdisciplinary programs of study.

Computational Science and Engineering

The Master of Science in Computational Science and Engineering (CSE SM) (*https://cse.mit.edu/programs/sm*) is an interdisciplinary program for students interested in the development, analysis, and application of computational approaches to science and engineering. The curriculum is designed with a common core serving all science and engineering disciplines and an elective component focusing on specific disciplinary topics. Students may pursue the CSE SM as a standalone degree or as leading to the CSE PhD program described below.

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

For more information, see the program descriptions under Interdisciplinary Graduate Programs.

Joint Program with the Woods Hole Oceanographic Institution

The Joint Program with the Woods Hole Oceanographic Institution (WHOI) (*http://mit.whoi.edu*) is intended for students whose primary career objective is oceanography or 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; thesis research may be advised by MIT or WHOI faculty. While in residence at MIT, students follow a program similar to that of other students in their home department. The program is described in more detail (*https://catalog.mit.edu/interdisciplinary/graduate-programs/joint-program-woods-hole-oceanographic-institution*) under Interdisciplinary Graduate Programs.

Leaders for Global Operations

The 24-month Leaders for Global Operations (LGO) (*https://catalog.mit.edu/interdisciplinary/graduate-programs/leaders-global-operations*) program combines graduate degrees in engineering and management for those with previous postgraduate work experience and strong undergraduate degrees in a technical field. During the two-year program, students complete a six-month internship at one of LGO's partner companies, where they conduct research that forms the basis of a dual-degree thesis. Students finish the program with two MIT degrees: an MBA (or SM in management) and an SM from one of eight engineering programs, some of which have optional or required LGO tracks. After graduation, alumni lead strategic initiatives in high-tech, operations, and manufacturing companies.

Polymers and Soft Matter

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

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

Technology and Policy

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) (*http://tpp.mit.edu*) 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, quantitative methods, and social science. 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. See the program description (*https://catalog.mit.edu/schools/mit-schwarzman-college-computing/data-systems-society*) under the Institute for Data, Systems, and Society.

Financial Support

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 MechE 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. (Please note that Master of Engineering in Manufacturing students are not eligible for RA or TA positions since their subject credits exceed these limits.)

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. Full-time 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 advisor. A limited number of awards and scholarships are available to graduate students directly through the department. A number of students are also supported by fellowships from outside agencies, such as the National Science Foundation, Office of Naval Research, and Department of Defense. Scholarships are awarded each year by the Society of Naval Architects and Marine Engineers. These awards are normally granted to applicants whose interest is focused on naval architecture and marine engineering or on ocean engineering. Applications are made directly to the granting agency, and inquiries for the fall term should be made in the preceding fall term.

Prospective students are invited to communicate with the Department regarding any of these educational and financial opportunities.

Experience has shown that the optimum graduate program consists of about equal measures of coursework and research, consistent with an RA appointment. The main advantage of a fellowship is a greater freedom in choosing a research project and advisor. 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 qualifying 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 on mechanical engineering graduate admissions, contact Una Sheehan. For general inquiries on the mechanical engineering graduate program, contact Leslie Regan. All can be reached in the MechE Graduate Office (*me-gradoffice@mit.edu*), Room 1-112, 617-253-2291.

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

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 Center for Biomedical Engineering, Center for Computational Science and Engineering, Computational and Systems Biology Program, Computer Science and Artificial Intelligence Laboratory, Institute for Soldier Nanotechnologies, Laboratory for Manufacturing and Productivity, Materials Research Science and Engineering Center, MIT Energy Initiative, Operations Research Center, Program in Polymers and Soft Matter, and Sea Grant College Program. Detailed information about many of these can be found under Research and Study and Interdisciplinary Graduate Programs. 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.

A partial list of departmental laboratories, listed according to the seven core areas of research, follows.

Mechanics: Modeling, Experimentation, and Computation

AMP Mechanical Behavior of Materials Laboratory
Mechanisms of deformation and fracture processes in engineering materials.

Center for Nonlinear Science
Interdisciplinary research into nonlinear phenomena. Incorporates the Nonlinear Dynamical Systems Lab (modeling, simulation, analysis), Nonlinear Dynamics Lab (experiments), and Nonlinear Systems Lab.

Composite Materials and Nondestructive Evaluation Laboratory
Development of quantitative nondestructive evaluation characterizations which are directly correlatable with the mechanical properties of materials and structures.

Finite Element Research Group
Computational procedures for the solution of problems in structural, solid, and fluid mechanics.

Hatsopoulos Microfluids Laboratory
Fundamental research on the behavior of complex fluid systems at microscopic scales, and associated engineering applications.

Design, Manufacturing, and Product Development

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.

Computer-Aided Design Laboratory
Advancing the state of the art in design methodology and computer-aided design methods.

Laboratory for Manufacturing and Productivity
An interdepartmental laboratory in the School of Engineering. Polymer microfabrication for microfluidic devices, chemical mechanical planarization for the semiconductor industry, precision macro- and micro-scale devices, and novel metrology methods for micro-scale devices. Small-scale fuel cells design, photovoltaic material and process research, and manufacture of photovoltaic panels. Identification technologies such as RFID, wireless sensors, and complex systems. Methods to integrate data and models across global networks. Factory-level manufacturing systems design and control, and supply chain design and management. Environmentally benign manufacturing.

Martin Center for Engineering Design
Design methodology, design of integrated electrical-mechanical systems, prototype development, advanced computer-aided design techniques.

Park Center for Complex Systems
Research to understand complexity, educating students and scholars on complexity, designing complex systems for the benefit of humankind, and disseminating knowledge on complexity to the world at large.

Precision Engineering Laboratory
Fundamental and applied research on all aspects of the design, manufacture, and control of high precision machines ranging from manufacturing machines to precision consumer products.

Precision Systems Design and Manufacturing Laboratory
Modeling, design, and manufacturing methods for nanopositioning equipment, carbon nanotube-based mechanisms and machines, and compliant mechanisms.

Controls, Instrumentation, and Robotics

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 Energy and Propulsion Research
Innovative science and technology for a sustainable energy future in a carbon-constrained world. Fundamental and applied research in energy conversion and transportation, with applications to low-carbon efficient energy and propulsion systems. Includes several research groups:

- *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.

- *Sloan Automotive Laboratory*. Processes and technology that control the performance, efficiency, and environmental impact of internal combustion engines, their lubrication, and fuel requirements.

Cryogenic Engineering Laboratory
Application of thermodynamics, heat transfer, and mechanical design to cryogenic processes and instrumentation and the operation of a liquid helium facility.

Rohsenow Kendall Heat Transfer Laboratory
Fundamental research in microscale/nanoscale transport, convection, laser/material interaction, and high heat fluxes; applied research in water purification, thermoelectric devices, energy-efficient buildings, and thermal management of electronics.

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:

- *Autonomous Marine Sensing Lab*. Distributed ocean sensing concepts for oceanographic science, national defense, and coastal management and protection. Oceanographic sensing and modeling, sonar system technology, computational underwater acoustics, and marine robotics and communication networking.
- *Design Lab*. Ship design, offshore structure design, marine robotics, geometric and solid modeling, advanced manufacturing, and shipbuilding. Includes the Center for Environmental Sensing and Modeling.
- *Experimental Hydrodynamics Lab*. Advanced surface ship, offshore platform, and underwater vehicle design. Development of non-invasive flow measurement and visualization methods.
- *Impact and Crashworthiness Laboratory*. Industry-oriented fracture testing and prediction technology of advanced high-strength steel sheets for automotive and shipbuilding applications. Includes both quasi-static and high strain rate response and effect of loading history on fracture.
- *Experimental and Nonlinear Dynamics Lab*. Laboratory experiments to obtain insight into all manner of dynamical phenomena, from micro-scale diffusive processes to global-scale oceanic wave fields. Field studies for ocean-related problems.
- *Laboratory for Ship and Platform Flows*. Modeling of free surface flows past conventional and high-speed vessels and estimation of their resistance and seakeeping in deep and shallow waters. Analytical and computational techniques.
- *Laboratory for Undersea Remote Sensing*. Ocean exploration, undersea remote sensing of marine life and geophysical phenomena, wave propagation and scattering theory in remote sensing, statistical estimation and information theory, acoustics and seismics, Europa exploration.
- *Marine Hydrodynamics Laboratory (Propeller Tunnel)*. A variable-pressure recirculating water tunnel capable of speeds up to 10 m/s. Experiments are performed using state-of-the-art measurement techniques and instrumentation.
- *Multidisciplinary Ocean Dynamics and Engineering Laboratory*. Complex physical and interdisciplinary oceanic dynamics and processes. Mathematical model and computation methods for ocean predictions, dynamical diagnostics, and for data assimilation and data-model comparisons.
- *Ocean Engineering Testing Tank*. The tank is 108 feet long, 8.5 feet wide, with an average depth of 4.5 feet. The wave generator can generate harmonic or random waves. The tank also houses several laser flow visualization systems.
- *Vortical Flow Research Laboratory*. Advanced capabilities for simulation of complex vertical flows. Powerful computer workstations and LINUX clusters, computer-video image conversion, and state-of-the-art flow simulation animation technologies.
- *MIT Sea Grant AUV Lab*. Dedicated to autonomous underwater vehicles (AUVs), the lab is a leading developer of advanced unmanned marine robots, with applications in oceanography, environmental monitoring, and underwater resource studies. It engages in instrumentation and algorithm development for underwater vehicles performing navigation- and information-intensive tasks. Various vehicle platforms, and fabrication tools and materials are available.

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.

Laboratory for Biomechanics of Cells and Biomolecules
Development of new instruments for the measurement of mechanical properties on the scale of a single cell or single molecule to better understand the interactions between biology and mechanics.

Newman Laboratory for Biomechanics and Human Rehabilitation
Research on bioinstrumentation, neuromuscular control, and technology for diagnosis and remediation of disabilities.

Nano/Micro Science and Technology

Pappalardo Laboratory for Micro/Nano Engineering
Creation of new engineering knowledge and products on the nano and micro scale through multidomain, multidisciplinary, and multiscale research.

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Professor of Mechanical Engineering
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Professor Post-Tenure of Mechanical Engineering

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Professor Emeritus of Mechanical Engineering

Tomasz Wierzbicki, PhD
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Professor Emeritus of Applied Mechanics

Gerald L. Wilson, PhD
Vannevar Bush Professor Emeritus
Professor Emeritus of Electrical Engineering
Professor Emeritus of Mechanical Engineering

First-Year Introductory Subjects

2.00A Designing for the Future: Earth, Sea, and Space
Prereq: Calculus I (GIR) and Physics I (GIR)
U (Spring)
3-3-3 units

Student teams formulate and complete space/earth/ocean exploration-based design projects with weekly milestones. Introduces core engineering themes, principles, and modes of thinking. Specialized learning modules enable teams to focus on the knowledge required to complete their projects, such as machine elements, electronics, design process, visualization and communication. Includes exercises in written and oral communication and team building. Examples of projects include surveying a lake for millfoil, from a remote controlled aircraft, and then sending out robotic harvesters to clear the invasive growth; and exploration to search for the evidence of life on a moon of Jupiter, with scientists participating through teleoperation and supervisory control of robots. Enrollment limited; preference to freshmen.
A. Techet

2.00B Toy Product Design
Prereq: None
U (Spring)
Not offered regularly; consult department
3-5-1 units

Provides students with an overview of design for entertainment and play, as well as opportunities in creative product design and community service. Students develop ideas for new toys that serve clients in the community, and work in teams with local sponsors and with experienced mentors on a themed toy design project. Students enhance creativity and experience fundamental aspects of the product development process, including determining customer needs, brainstorming, estimation, sketching, sketch modeling, concept development, design aesthetics, detailed design, and prototyping. Includes written, visual, and oral communication. Enrollment limited; preference to freshmen.
D. R. Wallace

2.S00 Special Subject in Mechanical Engineering
Prereq: None
U (Spring; second half of term)
Units arranged
Can be repeated for credit.

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

2.S01 Special Subject in Mechanical Engineering
Prereq: None
U (Spring; second half of term)
Units arranged

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

2.S02 Special Subject in Mechanical Engineering
Prereq: None
U (Spring)
Units arranged

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

2.00C[J] Design for Complex Environmental Issues
Same subject as 1.016[J], EC.746[J]
Prereq: None
U (Spring)
3-1-5 units

Working in small teams with real clients, students develop solutions related to the year's Terrascope topic. They have significant autonomy as they follow a full engineering design cycle from client profile through increasingly sophisticated prototypes to final product. Provides opportunities to acquire skills with power tools, workshop practice, design, product testing, and teamwork. Focuses on sustainability and appropriate technology that matches the client's specific situation and constraints. Products are exhibited in the public Bazaar of Ideas and evaluated by an expert panel. Class taught in collaboration with D-Lab and Beaver Works. Limited to first-year students. Open to students outside of Terrascope.
A. W. Epstein, J. Grimm, S. L. Hsu

Core Undergraduate Subjects

2.00 Introduction to Design
Prereq: None
U (Fall, Spring; second half of term)
2-2-2 units

Project-based introduction to product development and engineering design. Emphasizes key elements of the design process, including defining design problems, generating ideas, and building solutions. Presents a range of design techniques to help students think about, evaluate, and communicate designs, from sketching to physical prototyping, as well as other types of modeling. Students work both individually and in teams.
M. Yang

2.000 Explorations in Mechanical Engineering
Prereq: None
U (Spring)
Not offered regularly; consult department
2-0-0 units

Broad introduction to the various aspects of mechanical engineering at MIT, including mechanics, design, controls, energy, ocean engineering, bioengineering, and micro/nano engineering through a variety of experiences, including discussions led by faculty, students, and industry experts. Reviews research opportunities and undergraduate major options in Course 2 as well as a variety of career paths pursued by alumni. Subject can count toward the 6-unit discovery-focused credit limit for first year students.
A. Nasto

2.001 Mechanics and Materials I
Prereq: Physics I (GIR); *Coreq: 2.087 or 18.03*
U (Fall, Spring)
4-1-7 units. REST

Introduction to statics and the mechanics of deformable solids. Emphasis on the three basic principles of equilibrium, geometric compatibility, and material behavior. Stress and its relation to force and moment; strain and its relation to displacement; linear elasticity with thermal expansion. Failure modes. Application to simple engineering structures such as rods, shafts, beams, and trusses. Application to biomechanics of natural materials and structures.
S. Socrate, M. Culpepper, D. Parks, K. Kamrin

2.002 Mechanics and Materials II
Prereq: Chemistry (GIR) and 2.001
U (Spring)
3-3-6 units

Introduces mechanical behavior of engineering materials, and the use of materials in mechanical design. Emphasizes the fundamentals of mechanical behavior of materials, as well as design with materials. Major topics: elasticity, plasticity, limit analysis, fatigue, fracture, and creep. Materials selection. Laboratory experiments involving projects related to materials in mechanical design. Enrollment may be limited due to laboratory capacity; preference to Course 2 majors and minors.
L. Anand, K. Kamrin, P. Reis

2.003[J] Dynamics and Control I
Same subject as 1.053[J]
Prereq: Physics II (GIR); *Coreq: 2.087 or 18.03*
U (Fall, Spring)
4-1-7 units. REST

Introduction to the dynamics and vibrations of lumped-parameter models of mechanical systems. Kinematics. Force-momentum formulation for systems of particles and rigid bodies in planar motion. Work-energy concepts. Virtual displacements and virtual work. Lagrange's equations for systems of particles and rigid bodies in planar motion. Linearization of equations of motion. Linear stability analysis of mechanical systems. Free and forced vibration of linear multi-degree of freedom models of mechanical systems; matrix eigenvalue problems.
J. K. Vandiver, N. C. Makris, N. M. Patrikalakis, T. Peacock, D. Gossard, K. Turitsyn

2.004 Dynamics and Control II
Prereq: Physics II (GIR) and 2.003[J]
U (Fall, Spring)
4-2-6 units

Modeling, analysis, and control of dynamic systems. System modeling: lumped parameter models of mechanical, electrical, and electromechanical systems; interconnection laws; actuators and sensors. Linear systems theory: linear algebra; Laplace transform; transfer functions, time response and frequency response, poles and zeros; block diagrams; solutions via analytical and numerical techniques; stability. Introduction to feedback control: closed-loop response; PID compensation; steady-state characteristics, root-locus design concepts, frequency-domain design concepts. Laboratory experiments and control design projects. Enrollment may be limited due to laboratory capacity; preference to Course 2 majors and minors.
D. Del Vecchio, D. Trumper

2.005 Thermal-Fluids Engineering I
Prereq: (Physics II (GIR), 18.03, and (2.086, 6.100B, or 18.06)) or permission of instructor
U (Fall, Spring)
5-0-7 units

Integrated development of the fundamental principles of thermodynamics, fluid mechanics, and heat transfer, with applications. Focuses on the first and second laws of thermodynamics, mass conservation, and momentum conservation, for both closed and open systems. Entropy generation and its influence on the performance of engineering systems. Introduction to dimensionless numbers. Introduction to heat transfer: conduction, convection, and radiation. Steady-state and transient conduction. Finned surfaces. The heat equation and the lumped capacitance model. Coupled and uncoupled fluid models. Hydrostatics. Inviscid flow analysis and Bernoulli equation. Navier-Stokes equation and its solutions. Viscous internal flows, head losses, and turbulence. Introduction to pipe flows and Moody chart.
A. Henry

2.006 Thermal-Fluids Engineering II
Prereq: 2.005
U (Fall, Spring)
5-0-7 units

Focuses on the application of the principles of thermodynamics, heat transfer, and fluid mechanics to the design and analysis of engineering systems. Dimensional analysis, similarity, and modeling. Pipe systems: major and minor losses. Laminar and turbulent boundary layers. Boundary layer separation, lift and drag on objects. Heat transfer associated with laminar and turbulent flow of fluids in free and forced convection in channels and over surfaces. Pure substance model. Heat transfer in boiling and condensation. Thermodynamics and fluid mechanics of steady flow components of thermodynamic plants. Heat exchanger design. Power cycles and refrigeration plants. Design of thermodynamic plants. Analyses for alternative energy systems. Multi-mode heat transfer and fluid flow in thermodynamic plants.
R. Karnik, B. Gallant

2.007 Design and Manufacturing I
Prereq: 2.001 and 2.670; *Coreq: 2.086*
U (Spring)
3-4-5 units

Develops students' competence and self-confidence as design engineers. Emphasis on the creative design process bolstered by application of physical laws. Instruction on how to complete projects on schedule and within budget. Robustness and manufacturability are emphasized. Subject relies on active learning via a major design-and-build project. Lecture topics include idea generation, estimation, concept selection, visual thinking, computer-aided design (CAD), mechanism design, machine elements, basic electronics, technical communication, and ethics. Lab fee. Limited enrollment. Pre-registration required for lab assignment; special sections by lottery only.
S. Kim, A. Winter

2.008 Design and Manufacturing II
Prereq: 2.007; or *Coreq: 2.017[J] and (2.005 or 2.051)*
U (Fall, Spring)
3-3-6 units. Partial Lab

Integration of design, engineering, and management disciplines and practices for analysis and design of manufacturing enterprises. Emphasis is on the physics and stochastic nature of manufacturing processes and systems, and their effects on quality, rate, cost, and flexibility. Topics include process physics and control, design for manufacturing, and manufacturing systems. Group project requires design and fabrication of parts using mass-production and assembly methods to produce a product in quantity. Six units may be applied to the General Institute Lab Requirement. Satisfies 6 units of Institute Laboratory credit. Enrollment may be limited due to laboratory capacity; preference to Course 2 majors and minors.
J.-H. Chun, J. Hart, S.G. Kim, J. Liu, W. Seering, D. Wendell

2.009 The Product Engineering Process
Prereq: 2.001, 2.003[J], (2.005 or 2.051), and (2.00B, 2.670, or 2.678)
U (Fall)
3-3-9 units

Students develop an understanding of product development phases and experience working in teams to design and construct high-quality product prototypes. Design process learned is placed into a broader development context. Primary goals are to improve ability to reason about design alternatives and apply modeling techniques appropriate for different development phases; understand how to gather and process customer information and transform it into engineering specifications; and use teamwork to resolve the challenges in designing and building a substantive product prototype. Instruction and practice in oral communication provided. Enrollment may be limited due to laboratory capacity; preference to Course 2 seniors.
D. R. Wallace

2.013 Engineering Systems Design
Subject meets with 2.733
Prereq: (2.001, 2.003[J], (2.005 or 2.051), and (2.00B, 2.670, or 2.678)) or permission of instructor
U (Fall)
0-6-6 units

Focuses on the design of engineering systems to satisfy stated performance, stability, and/or control requirements. Emphasizes individual initiative, application of fundamental principles, and the compromises inherent in the engineering design process. Culminates in the design of an engineering system, typically a vehicle or other complex system. Includes instruction and practice in written and oral communication through team presentations, design reviews, and written reports. Students taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity; preference to Course 2 majors and minors.
D. Hart

2.014 Engineering Systems Development
Subject meets with 2.734
Prereq: (2.001, 2.003[J], (2.005 or 2.051), and (2.00B, 2.670, or 2.678)) or permission of instructor
U (Spring)
0-6-6 units
Can be repeated for credit.

Focuses on implementation and operation of engineering systems. Emphasizes system integration and performance verification using methods of experimental inquiry. Students refine their subsystem designs and the fabrication of working prototypes. Includes experimental analysis of subsystem performance and comparison with physical models of performance and with design goals. Component integration into the full system, with detailed analysis and operation of the complete vehicle in the laboratory and in the field. Includes written and oral reports. Students carry out formal reviews of the overall system design. Instruction and practice in oral and written communication provided. Students taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity; preference to Course 2 majors and minors.
D. Hart

2.016 Hydrodynamics
Prereq: 2.005
U (Fall)
3-0-9 units

Covers fundamental principles of fluid mechanics and applications to practical ocean engineering problems. Basic geophysical fluid mechanics, including the effects of salinity, temperature, and density; heat balance in the ocean; large scale flows. Hydrostatics. Linear free surface waves, wave forces on floating and submerged structures. Added mass, lift and drag forces on submerged bodies. Includes final project on current research topics in marine hydrodynamics.
A. H. Techet

2.017[J] Design of Electromechanical Robotic Systems
Same subject as 1.015[J]
Prereq: 2.003[J], 2.016, and 2.678; *Coreq: 2.671*
U (Spring)
3-3-6 units. Partial Lab

Design, construction, and testing of field robotic systems, through team projects with each student responsible for a specific subsystem. Projects focus on electronics, instrumentation, and machine elements. Design for operation in uncertain conditions is a focus point, with ocean waves and marine structures as a central theme. Basic statistics, linear systems, Fourier transforms, random processes, spectra and extreme events with applications in design. Lectures on ethics in engineering practice included. Instruction and practice in oral and written communication provided. Satisfies 6 units of Institute Laboratory credit. Enrollment may be limited due to laboratory capacity.
M. Triantafyllou, M. Sacarny

2.019 Design of Ocean Systems
Prereq: 2.001, 2.003[J], and (2.005 or 2.016)
U (Spring)
3-3-6 units

Complete cycle of designing an ocean system using computational design tools for the conceptual and preliminary design stages. Team projects assigned, with each student responsible for a specific subsystem. Lectures cover hydrodynamics; structures; power and thermal aspects of ocean vehicles, environment, materials, and construction for ocean use; generation and evaluation of design alternatives. Focus on innovative design concepts chosen from high-speed ships, submersibles, autonomous vehicles, and floating and submerged deep-water offshore platforms. Lectures on ethics in engineering practice included. Instruction and practice in oral and written communication provided. Enrollment may be limited due to laboratory capacity; preference to Course 2 seniors.
C. Chryssostomidis, M. S. Triantafyllou

2.086 Numerical Computation for Mechanical Engineers
Prereq: Calculus II (GIR) and Physics I (GIR); *Coreq: 2.087 or 18.03*
U (Fall, Spring)
2-2-8 units. REST

Covers elementary programming concepts, including variable types, data structures, and flow control. Provides an introduction to linear algebra and probability. Numerical methods relevant to MechE, including approximation (interpolation, least squares, and statistical regression), integration, solution of linear and nonlinear equations, and ordinary differential equations. Presents deterministic and probabilistic approaches. Uses examples from MechE, particularly from robotics, dynamics, and structural analysis. Assignments require MATLAB programming. Enrollment may be limited due to laboratory capacity; preference to Course 2 majors and minors.
D. Frey, F. Hover, N. Hadjiconstantinou,

2.087 Engineering Mathematics: Linear Algebra and ODEs
Prereq: Calculus II (GIR) and Physics I (GIR)
U (Fall; first half of term)
Not offered regularly; consult department
2-0-4 units

Introduction to linear algebra and ordinary differential equations (ODEs), including general numerical approaches to solving systems of equations. Linear systems of equations, existence and uniqueness of solutions, Gaussian elimination. Initial value problems, 1st and 2nd order systems, forward and backward Euler, RK4. Eigenproblems, eigenvalues and eigenvectors, including complex numbers, functions, vectors and matrices.
A. Hosoi, T. Peacock

Dynamics and Acoustics

2.032 Dynamics
Prereq: 2.003[J]
G (Fall)
4-0-8 units

Review of momentum principles. Hamilton's principle and Lagrange's equations. Three-dimensional kinematics and dynamics of rigid bodies. Study of steady motions and small deviations therefrom, gyroscopic effects, causes of instability. Free and forced vibrations of lumped-parameter and continuous systems. Nonlinear oscillations and the phase plane. Nonholonomic systems. Introduction to wave propagation in continuous systems.
T. R. Akylas, T. Peacock, N. Hadjiconstantinou

2.033[J] Nonlinear Dynamics and Turbulence
Same subject as 1.686[J], 18.358[J]
Subject meets with 1.068
Prereq: 1.060A
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-2-7 units

See description under subject 1.686[J].
L. Bourouiba

2.034[J] Nonlinear Dynamics and Waves
Same subject as 1.685[J], 18.377[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

A unified treatment of nonlinear oscillations and wave phenomena with applications to mechanical, optical, geophysical, fluid, electrical and flow-structure interaction problems. Nonlinear free and forced vibrations; nonlinear resonances; self-excited oscillations; lock-in phenomena. Nonlinear dispersive and nondispersive waves; resonant wave interactions; propagation of wave pulses and nonlinear Schrodinger equation. Nonlinear long waves and breaking; theory of characteristics; the Korteweg-de Vries equation; solitons and solitary wave interactions. Stability of shear flows. Some topics and applications may vary from year to year.
R. R. Rosales

2.036[J] Nonlinear Dynamics and Chaos
Same subject as 18.385[J]
Prereq: 18.03 or 18.032
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

See description under subject 18.385[J].
R. R. Rosales

2.050[J] Nonlinear Dynamics: Chaos
Same subject as 12.006[J], 18.353[J]
Prereq: Physics II (GIR) and (18.03 or 18.032)
U (Fall)
3-0-9 units

See description under subject 12.006[J].
D. Rothman

2.060[J] Structural Dynamics
Same subject as 1.581[J], 16.221[J]
Subject meets with 1.058
Prereq: 18.03 or permission of instructor
G (Fall)
3-1-8 units

See description under subject 1.581[J].
T. Cohen

2.062[J] Wave Propagation
Same subject as 1.138[J], 18.376[J]
Prereq: 2.003[J] and 18.075
G (Spring)
Not offered regularly; consult department
3-0-9 units

Theoretical concepts and analysis of wave problems in science and engineering with examples chosen from elasticity, acoustics, geophysics, hydrodynamics, blood flow, nondestructive evaluation, and other applications. Progressive waves, group velocity and dispersion, energy density and transport. Reflection, refraction and transmission of plane waves by an interface. Mode conversion in elastic waves. Rayleigh waves. Waves due to a moving load. Scattering by a two-dimensional obstacle. Reciprocity theorems. Parabolic approximation. Waves on the sea surface. Capillary-gravity waves. Wave resistance. Radiation of surface waves. Internal waves in stratified fluids. Waves in rotating media. Waves in random media.
T. R. Akylas, R. R. Rosales

2.065 Acoustics and Sensing
Subject meets with 2.066
Prereq: 2.003[J], 6.3000, 8.03, or 16.003
U (Spring)
3-0-9 units

Introduces the fundamental concepts of acoustics and sensing with waves. Provides a unified theoretical approach to the physics of image formation through scattering and wave propagation in sensing. The linear and nonlinear acoustic wave equation, sources of sound, including musical instruments. Reflection, refraction, transmission and absorption. Bearing and range estimation by sensor array processing, beamforming, matched filtering, and focusing. Diffraction, bandwidth, ambient noise and reverberation limitations. Scattering from objects, surfaces and volumes by Green's Theorem. Forward scatter, shadows, Babinet's principle, extinction and attenuation. Ray tracing and waveguides in remote sensing. Applications to acoustic, radar, seismic, thermal and optical sensing and exploration. Students taking the graduate version complete additional assignments.
N. C. Makris

2.066 Acoustics and Sensing
Subject meets with 2.065
Prereq: 2.003[J], 6.3000, 8.03, 16.003, or permission of instructor
G (Spring)
3-0-9 units

Introduces the fundamental concepts of acoustics and sensing with waves. Provides a unified theoretical approach to the physics of image formation through scattering and wave propagation in sensing. The linear and nonlinear acoustic wave equation, sources of sound, including musical instruments. Reflection, refraction, transmission and absorption. Bearing and range estimation by sensor array processing, beamforming, matched filtering, and focusing. Diffraction, bandwidth, ambient noise and reverberation limitations. Scattering from objects, surfaces and volumes by Green's Theorem. Forward scatter, shadows, Babinet's principle, extinction and attenuation. Ray tracing and waveguides in remote sensing. Applications to acoustic, radar, seismic, thermal and optical sensing and exploration. Students taking the graduate version of the subject complete additional assignments.
N. C. Makris

Solid Mechanics and Materials

2.071 Mechanics of Solid Materials
Prereq: 2.002
G (Spring)
4-0-8 units

Fundamentals of solid mechanics applied to the mechanical behavior of engineering materials. Kinematics of deformation, stress, and balance principles. Isotropic linear elasticity and isotropic linear thermal elasticity. Variational and energy methods. Linear viscoelasticity. Small-strain elastic-plastic deformation. Mechanics of large deformation; nonlinear hyperelastic material behavior. Foundations and methods of deformable-solid mechanics, including relevant applications. Provides base for further study and specialization within solid mechanics, including continuum mechanics, computational mechanics (e.g., finite-element methods), plasticity, fracture mechanics, structural mechanics, and nonlinear behavior of materials.
L. Anand, D. M. Parks

2.072 Mechanics of Continuous Media
Prereq: 2.071
G (Fall)
Not offered regularly; consult department
3-0-9 units

Principles and applications of continuum mechanics. Kinematics of deformation. Thermomechanical conservation laws. Stress and strain measures. Constitutive equations including some examples of their microscopic basis. Solution of some basic problems for various materials as relevant in materials science, fluid dynamics, and structural analysis. Inherently nonlinear phenomena in continuum mechanics. Variational principles.
L. Anand

2.073 Solid Mechanics: Plasticity and Inelastic Deformation
Prereq: 2.071
G (Fall)
3-0-9 units

Physical basis of plastic/inelastic deformation of solids; metals, polymers, granular/rock-like materials. Continuum constitutive models for small and large deformation of elastic-(visco)plastic solids. Analytical and numerical solution of selected boundary value problems. Applications to deformation processing of metals.
L. Anand, D. M. Parks

2.074 Solid Mechanics: Elasticity
Prereq: 2.002 and 18.03
G (Fall)
3-0-9 units

Introduction to the theory and applications of nonlinear and linear elasticity. Strain, stress, and stress-strain relations. Several of the following topics: Spherically and cylindrically symmetric problems. Anisotropic material behavior. Piezoelectric materials. Effective properties of composites. Structural mechanics of beams and plates. Energy methods for structures. Two-dimensional problems. Stress concentration at cavities, concentrated loads, cracks, and dislocations. Variational methods and their applications; introduction to the finite element method. Introduction to wave propagation.
R. Abeyaratne

2.075 Mechanics of Soft Materials
Prereq: None
G (Fall)
3-0-9 units

Covers a number of fundamental topics in the emerging field of soft and active materials, including polymer mechanics and physics, poroelasticity, viscoelasticity, and mechanics of electro-magneto-active and other responsive polymers. Lectures, recitations, and experiments elucidate the basic mechanical and thermodynamic principles underlying soft and active materials. Develops an understanding of the fundamental mechanisms for designing soft materials that possess extraordinary properties, such as stretchable, tough, strong, resilient, adhesive and responsive to external stimuli, from molecular to bulk scales.
X. Zhao

2.076[J] Mechanics of Heterogeneous Materials
Same subject as 16.223[J]
Prereq: 2.002, 3.032, 16.20, or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

See description under subject 16.223[J].
B. L. Wardle, S-G. Kim

2.077 Solid Mechanics: Coupled Theories
Prereq: 2.072
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Complex problems in solid mechanics for a wide range of applications require a knowledge of the foundational balance laws of mechanics, thermodynamics, and electrodynamics of continua, together with a knowledge of the structure and properties of the materials which are provided by particular constitutive models for the so-called smart-materials, and the materials used in the many applications that involve thermo-, chemo-, electro- and/or magneto-mechanical coupling. Reviews the basic balance laws and the constitutive equations of the classical coupled theories of thermoelasticity and poroelasticity, and provides an introduction to the nonlinear theories of electroelasticity and magnetoelasticity. Examines the governing coupled partial differential equations and suitable boundary conditions. Discusses numerical solutions of the partial differential equations.
L. Anand

2.080[J] Structural Mechanics
Same subject as 1.573[J]
Prereq: 2.002
G (Fall)
4-0-8 units

Applies solid mechanics fundamentals to the analysis of marine, civil, and mechanical structures. Continuum concepts of stress, deformation, constitutive response and boundary conditions are reviewed in selected examples. The principle of virtual work guides mechanics modeling of slender structural components (e.g., beams; shafts; cables, frames; plates; shells), leading to appropriate simplifying assumptions. Introduction to elastic stability. Material limits to stress in design. Variational methods for computational structural mechanics analysis.
T. Wierzbicki, D. Parks

2.081[J] Plates and Shells: Static and Dynamic Analysis
Same subject as 16.230[J]
Prereq: 2.071, 2.080[J], or permission of instructor
G (Spring)
3-1-8 units

Stress-strain relations for plate and shell elements. Differential equations of equilibrium. Energy methods and approximate solutions. Bending and buckling of rectangular plates. Post-buckling and ultimate strength of cold formed sections and typical stiffened panels used in aerospace, civil, and mechanical engineering; offshore technology; and ship building. Geometry of curved surfaces. General theory of elastic, axisymmetric shells and their equilibrium equations. Buckling, crushing and bending strength of cylindrical shells with applications. Propagation of 1-D elastic waves in rods, geometrical and material dispersion. Plane, Rayleigh surface, and 3-D waves. 1-D plastic waves. Response of plates and shells to high-intensity loads. Dynamic plasticity and fracture. Application to crashworthiness and impact loading of structures.
T. Sapsis

2.082 Ship Structural Analysis and Design
Prereq: 2.081[J] and 2.701
G (Spring; second half of term)
3-0-3 units

Design application of analysis developed in 2.081[J]. Ship longitudinal strength and hull primary stresses. Ship structural design concepts. Design limit states including plate bending, column and panel buckling, panel ultimate strength, and plastic analysis. Matrix stiffness, and introduction to finite element analysis. Computer projects on the structural design of a midship module.
R. S. McCord, T. Wierzbicki

2.083[J] Topology Optimization of Structures (New)
Same subject as 1.583[J], 16.215[J]
Prereq: None
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units

See description under subject 1.583[J].
J. Carstensen

Computational Engineering

2.0911[J] Computational Design and Fabrication
Same subject as 6.4420[J]
Subject meets with 6.8420
Prereq: Calculus II (GIR) and (6.1010 or permission of instructor)
U (Spring)
3-0-9 units

See description under subject 6.4420[J].
W. Matusik

2.095 Introduction to Finite Element Methods
Subject meets with 2.098
Prereq: 2.086 or permission of instructor
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Ordinary differential equation boundary value problems: 2nd-order, 4th-order spatial operators, eigenproblems. Partial differential equations for scalar fields: elliptic, parabolic, hyperbolic. Strong statement, weak form, minimization principle. Rayleigh-Ritz, Galerkin projection. Numerical interpolation, integration, differentiation, best-fit. Finite element method for spatial discretization in one and two space dimensions: formulation (linear, quadratic approximation), mesh generation, bases and discrete equations, uniform and adaptive refinement, a priori and a posteriori error estimates, sparse solvers, implementation, testing. Finite difference-finite element methods for mixed initial-boundary value problems; nonlinear problems and Newton iteration; linear elasticity. Applications in heat transfer and structural analysis. Assignments require MATLAB coding. Students taking graduate version complete additional work.
A. Patera

2.096[J] Introduction to Modeling and Simulation
Same subject as 6.7300[J], 16.910[J]
Prereq: 18.03 or 18.06
G (Fall)
3-6-3 units

See description under subject 6.7300[J].
L. Daniel

2.097[J] Numerical Methods for Partial Differential Equations
Same subject as 6.7330[J], 16.920[J]
Prereq: 18.03 or 18.06
G (Fall)
3-0-9 units

See description under subject 16.920[J].
J. Peraire

2.098 Introduction to Finite Element Methods
Subject meets with 2.095
Prereq: 2.086 or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Ordinary differential equation boundary value problems: 2nd-order, 4th-order spatial operators; eigenproblems. Partial differential equations for scalar fields: elliptic, parabolic, hyperbolic. Strong statement, weak form, minimization principle. Rayleigh-Ritz, Galerkin projection. Numerical interpolation, integration, differentiation; best-fit. Finite element method for spatial discretization in one and two space dimensions: formulation (linear, quadratic approximation), mesh generation, bases and discrete equations, uniform and adaptive refinement, a priori and a posteriori error estimates, sparse solvers, implementation, testing. Finite difference-finite element methods for mixed initial-boundary value problems; nonlinear problems and Newton iteration; linear elasticity. Applications in heat transfer and structural analysis. Assignments require MATLAB coding. Students taking graduate version complete additional work.
A. Patera

2.099[J] Computational Mechanics of Materials
Same subject as 16.225[J]
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

See description under subject 16.225[J].
R. Radovitzky

System Dynamics and Control

2.110 Information, Entropy, and Computation
Prereq: Physics I (GIR)
U (Fall)
Not offered regularly; consult department
3-0-6 units

Explores the ultimate limits to communication and computation, with an emphasis on the physical nature of information and information processing. Topics include information and computation, digital signals, codes, and compression. Biological representations of information. Logic circuits, computer architectures, and algorithmic information. Noise, probability, and error correction. The concept of entropy applied to channel capacity and to the second law of thermodynamics. Reversible and irreversible operations and the physics of computation. Quantum computation.
P. Penfield, Jr.

2.111[J] Quantum Computation
Same subject as 6.6410[J], 8.370[J], 18.435[J]
Prereq: 8.05, 18.06, 18.700, 18.701, or 18.C06[J]
G (Fall)
3-0-9 units

See description under subject 18.435[J].
I. Chuang, A. Harrow, P. Shor

2.12 Introduction to Robotics
Subject meets with 2.120
Prereq: 2.004
U (Spring)
3-2-7 units

Cross-disciplinary studies in robot mechanics and intelligence. Emphasizes physical understanding of robot kinematics and dynamics, differential motion and energy method, design and control of robotic arms and mobile robots, and actuators, drives, and transmission. Second half of course focuses on algorithmic thinking and computation, computer vision and perception, planning and control for manipulation, localization and navigation, machine learning for robotics, and human-robot systems. Weekly laboratories include brushless DC motor control, design and fabrication of robotic arms and vehicles, robot vision and navigation, and programming and system integration using Robot Operating System (ROS). Group term project builds intelligent robots for specific applications of interest. Students taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity; preference to Course 2 majors and minors.
H. Asada

2.120 Introduction to Robotics
Subject meets with 2.12
Prereq: 2.004 or permission of instructor
G (Spring)
3-2-7 units

Cross-disciplinary studies in robot mechanics and intelligence. Emphasizes physical understanding of robot kinematics and dynamics, differential motion and energy method, design and control of robotic arms and mobile robots, and actuators, drives, and transmission. Second half of course focuses on algorithmic thinking and computation, computer vision and perception, planning and control for manipulation, localization and navigation, machine learning for robotics, and human-robot systems. Weekly laboratories include brushless DC motor control, design and fabrication of robotic arms and vehicles, robot vision and navigation, and programming and system integration using Robot Operating System (ROS). Group term project builds intelligent robots for specific applications of interest. Students taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity.
H. Asada

2.121 Stochastic Systems
Subject meets with 2.122, 2.22
Prereq: None. *Coreq: 2.004*
U (Spring)
3-0-9 units

Response of systems to stochastic excitation with design applications. Linear time-invariant systems, convolution, Fourier and Laplace transforms. Probability and statistics. Discrete and continuous random variables, derived distributions. Stochastic processes, auto-correlation. Stationarity and ergodicity, power spectral density. Systems driven by random functions, Wiener-Khinchine theorem. Sampling and filtering. Short- and long-term statistics, statistics of extremes. Problems from mechanical vibrations and statistical linearization, statistical mechanics, and system prediction/identification. Students taking graduate version complete additional assignments and a short-term project.
N. M. Patrikalakis, T. P. Sapsis, M. S. Triantafyllou

2.122 Stochastic Systems
Subject meets with 2.121, 2.22
Prereq: 2.004 and 2.087
G (Spring)
4-0-8 units

Response of systems to stochastic excitation with design applications. Linear time-invariant systems, convolution, Fourier and Laplace transforms. Probability and statistics. Discrete and continuous random variables, derived distributions. Stochastic processes, auto-correlation. Stationarity and ergodicity, power spectral density. Systems driven by random functions, Wiener-Khinchine theorem. Sampling and filtering. Short- and long-term statistics, statistics of extremes. Problems from mechanical vibrations and statistical linearization, statistical mechanics, and system prediction/identification. Students taking graduate version complete additional assignments and a short-term project.
N. M. Patrikalakis, T. P. Sapsis, M. S. Triantafyllou

2.124[J] Robotics: Science and Systems
Same subject as 6.4200[J], 16.405[J]
Prereq: ((1.00 or 6.100A) and (2.003[J], 6.1010, 6.1210, or 16.06)) or permission of instructor
U (Spring)
2-6-4 units. Institute LAB

See description under subject 6.4200[J]. Enrollment limited.
L. Carlone, S. Karaman, D. Hadfield-Manell, J. Leonard

2.131 Advanced Instrumentation and Measurement
Prereq: Permission of instructor
G (Spring)
3-6-3 units

Provides training in advanced instrumentation and measurement techniques. Topics include system level design, fabrication and evaluation with emphasis on systems involving concepts and technology from mechanics, optics, electronics, chemistry and biology. Simulation, modeling and design software. Use of a wide range of instruments/techniques (e.g., scanning electron microscope, dynamic signal/system analyzer, impedance analyzer, laser interferometer) and fabrication/machining methods (e.g., laser micro-machining, 3D printing, computer controlled turning, and machining centers). Theory and practice of both linear and nonlinear system identification techniques. Lab sessions include instruction and group project work. No final exam.
I. W. Hunter

2.132 Instrumentation and Measurement: MICA Projects (New)
Subject meets with 2.133
Prereq: 2.671 or permission of instructor
U (Fall)
3-6-3 units

Engages students in project-based learning by using a wide variety of experimental setups called MICA (Measurement, Instrumentation, Control, and Analysis) Workstations to learn about sensors, actuators, instrumentation, and measurement techniques. Over 50 MICA Workstations allow experiments to be performed on a broad range of phenomena including those found in optics, electronics, acoustics, biology, botany, material science, mechanics, thermal, and fluid systems. Experiments utilize Mathematica Notebooks in which students conduct data analysis and model fitting, and complete homework assignments. The integration of ChatGPT into Mathematica provides help in the learning process. Students also build new Workstations guided by CAD models and develop the Mathematica code to run experiments, perform data analyses, and model parameter estimation. Students taking graduate version build more sophisticated Workstations..
I. Hunter

2.133 Instrumentation and Measurement: MICA Projects (New)
Subject meets with 2.132
Prereq: Permission of instructor
G (Fall)
3-6-3 units

Engages students in project-based learning by using a wide variety of experimental setups called MICA (Measurement, Instrumentation, Control, and Analysis) Workstations to learn about sensors, actuators, instrumentation, and measurement techniques. Over 50 MICA Workstations allow experiments to be performed on a broad range of phenomena including those found in optics, electronics, acoustics, biology, botany, material science, mechanics, thermal, and fluid systems. Experiments utilize Mathematica Notebooks in which students conduct data analysis and model fitting, and complete homework assignments. The integration of ChatGPT into Mathematica provides help in the learning process. Students also build new Workstations guided by CAD models and develop the Mathematica code to run experiments, perform data analyses, and model parameter estimation. Students taking graduate version build more sophisticated Workstations.
I. Hunter

2.14 Analysis and Design of Feedback Control Systems
Subject meets with 2.140
Prereq: 2.004
U (Spring)
3-3-6 units

Develops the fundamentals of feedback control using linear transfer function system models. Analysis in time and frequency domains. Design in the s-plane (root locus) and in the frequency domain (loop shaping). Describing functions for stability of certain non-linear systems. Extension to state variable systems and multivariable control with observers. Discrete and digital hybrid systems and use of z-plane design. Extended design case studies and capstone group projects. Students taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity; preference to Course 2 majors and minors.
D. L. Trumper, K. Youcef-Toumi

2.140 Analysis and Design of Feedback Control Systems
Subject meets with 2.14
Prereq: 2.004 or permission of instructor
G (Spring)
3-3-6 units

Develops the fundamentals of feedback control using linear transfer function system models. Analysis in time and frequency domains. Design in the s-plane (root locus) and in the frequency domain (loop shaping). Describing functions for stability of certain non-linear systems. Extension to state variable systems and multivariable control with observers. Discrete and digital hybrid systems and use of z-plane design. Extended design case studies and capstone group projects. Student taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity.
D. Rowell, D. L. Trumper, K. Youcef-Toumi

2.141 Modeling and Simulation of Dynamic Systems
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

Modeling multidomain engineering systems at a level of detail suitable for design and control system implementation. Network representation, state-space models; multiport energy storage and dissipation, Legendre transforms; nonlinear mechanics, transformation theory, Lagrangian and Hamiltonian forms; Control-relevant properties. Application examples may include electro-mechanical transducers, mechanisms, electronics, fluid and thermal systems, compressible flow, chemical processes, diffusion, and wave transmission.
N. Hogan

2.145 Design of Compliant Mechanisms, Machines and Systems
Subject meets with 2.147
Prereq: 2.003[J] and 2.007
U (Fall)
3-3-6 units

Design, modeling and integration of compliance into systems that enable performance which is impractical to obtain via rigid mechanisms. Includes multiple strategies (pseudo-rigid body, topology synthesis, freedom and constraint topology) to engineer compliant mechanisms for mechanical systems. Emphasis is placed upon the integration of first principles (math/physics/engineering classes) to optimize kinematics, stiffness, energy storage/release, load capacity, efficiency and integration with actuation/sensing. Synthesize concepts, optimize them via computational models and test prototypes. Prototypes integrate multiple engineering sub-disciplines (e.g. mechanics + dynamics or mechanics + energy) and are drawn from biological systems, prosthetics, energy harvesting, precision instrumentation, robotics, space-based systems and others. Students taking graduate version complete additional assignments.
M. Culpepper

2.147 Design of Compliant Mechanisms, Machines and Systems
Subject meets with 2.145
Prereq: 2.003[J] and 2.007
G (Fall)
3-3-6 units

Design, modeling and integration of compliance into systems that enable performance which is impractical to obtain via rigid mechanisms. Students learn strategies (pseudo-rigid body, topology synthesis, freedom and constraint topology) to engineer compliant mechanisms for mechanical systems. Emphasis is placed upon the integration of first principles (math/physics/engineering classes) to optimize kinematics, stiffness, energy storage/release, load capacity, efficiency and integration with actuation/sensing. Students synthesize concepts, optimize them via computational models and test prototypes. Prototypes integrate multiple engineering sub-disciplines (e.g. mechanics + dynamics or mechanics + energy) and are drawn from biological systems, prosthetics, energy harvesting, precision instrumentation, robotics, space-based systems and others. Students taking graduate version complete additional assignments.
M. Culpepper

2.151 Advanced System Dynamics and Control
Prereq: 2.004 and (2.087 or 18.06)
G (Fall)
4-0-8 units

Analytical descriptions of state-determined dynamic physical systems; time and frequency domain representations; system characteristics - controllability, observability, stability; linear and nonlinear system responses. Modification of system characteristics using feedback. State observers, Kalman filters. Modeling/performance trade-offs in control system design. Basic optimization tools. Positive systems. Emphasizes applications to physical systems.
J.-J. E. Slotine, K. Youcef-Toumi, N. Hogan

2.152[J] Nonlinear Control
Same subject as 9.110[J]
Prereq: 2.151, 6.7100[J], 16.31, or permission of instructor
G (Spring)
3-0-9 units

Introduction to nonlinear control and estimation in physical and biological systems. Nonlinear stability theory, Lyapunov analysis, Barbalat's lemma. Feedback linearization, differential flatness, internal dynamics. Sliding surfaces. Adaptive nonlinear control and estimation. Multiresolution bases, nonlinear system identification. Contraction analysis, differential stability theory. Nonlinear observers. Asynchronous distributed computation and learning. Concurrent synchronization, polyrhythms. Monotone nonlinear systems. Emphasizes application to physical systems (robots, aircraft, spacecraft, underwater vehicles, reaction-diffusion processes, machine vision, oscillators, internet), machine learning, computational neuroscience, and systems biology. Includes term projects.
J.-J. E. Slotine

2.153 Adaptive Control and Connections to Machine Learning
Prereq: 2.151
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Lays the foundation of adaptive control, and investigates its interconnections with machine learning. Explores fundamental principles of adaptive control, including parameter estimation, recursive algorithms, stability properties, and conditions for convergence. Studies their relationship with machine learning, including the minimization of a performance error and fast convergence. Discusses robustness and regularization in both fields. Derives conditions of learning and implications of imperfect learning. Examines the trade-off between stability and learning. Focuses throughout the term on dynamic systems and on problems where real-time control is needed. Uses examples from aerospace, propulsion, automotive, and energy systems to elucidate the underlying concepts.
A. Annaswamy

2.154 Maneuvering and Control of Surface and Underwater Vehicles
Prereq: 2.22
G (Fall)
3-0-9 units

Maneuvering motions of surface and underwater vehicles. Derivation of equations of motion, hydrodynamic coefficients. Memory effects. Linear and nonlinear forms of the equations of motion. Control surfaces modeling and design. Engine, propulsor, and transmission systems modeling and simulation during maneuvering. Stability of motion. Principles of multivariable automatic control. Optimal control, Kalman filtering, loop transfer recovery. Term project: applications chosen from autopilots for surface vehicles; towing in open seas; remotely operated vehicles.
M. S. Triantafyllou

2.155 Artificial Intelligence and Machine Learning for Engineering Design
Subject meets with 2.156
Prereq: 2.086, 6.100A, or permission of instructor
U (Fall)
3-0-9 units

Machine learning and artificial intelligence techniques in engineering design applications. Emphasizes state-of-the-art machine learning techniques to design new products or systems or solve complex engineering problems. Lectures cover the theoretical and practical aspects of machine learning and optimization methods. Challenge problems, research paper discussions, and interactive in-class activities are used to highlight the unique challenges of machine learning for design applications. A group term project on students' applications of interest. Basic programming and machine learning familiarity are recommended. Students taking graduate version complete additional assignments.
F. Ahmed

2.156 Artificial Intelligence and Machine Learning for Engineering Design
Subject meets with 2.155
Prereq: None
G (Fall)
3-0-9 units

Machine learning and artificial intelligence techniques in engineering design applications. Emphasizes state-of-the-art machine learning techniques to design new products or systems or solve complex engineering problems. Lectures cover the theoretical and practical aspects of machine learning and optimization methods. Challenge problems, research paper discussions, and interactive in-class activities are used to highlight the unique challenges of machine learning for design applications. A group term project on students' applications of interest. Basic programming and machine learning familiarity are recommended. Students taking graduate version complete additional assignments.
F. Ahmed

2.16 Learning Machines
Subject meets with 2.168
Prereq: 2.086, 18.075, and (6.3700 or 18.05)
U (Spring)
Not offered regularly; consult department
4-0-8 units

Introduces fundamental concepts and encourages open-ended exploration of the increasingly topical intersection between artificial intelligence and the physical sciences. Energy and information, and their respective optimality conditions are used to define supervised and unsupervised learning algorithms; as well as ordinary and partial differential equations. Subsequently, physical systems with complex constitutive relationships are drawn from elasticity, biophysics, fluid mechanics, hydrodynamics, acoustics, and electromagnetics to illustrate how machine learning-inspired optimization can approximate solutions to forward and inverse problems in these domains.
G. Barbastathis

2.160 Identification, Estimation, and Learning
Prereq: 2.151, 6.7100[J], 16.31, or permission of instructor
G (Fall)
3-0-9 units

Provides a broad theoretical basis for estimation, identification, and learning of linear and nonlinear systems at the cross-disciplinary area of system dynamics and control, machine learning, and statistics. Recursive least squares estimate, partial least squares, Kalman filter and extended Kalman filter, Bayes filter and particle filter; parametric and non-parametric system identification, Wiener-Hopf equation, persistent excitation, unbiased estimates, asymptotic variance, experiment design; function approximation theory, neural nets, radial basis functions, Koopman operator for exact linearization of nonlinear systems, and dynamic mode decomposition. Context-oriented mini-projects: robotics, self-driving cars, biomedical engineering, wearable sensors.
H. Asada

2.165[J] Robotics
Same subject as 9.175[J]
Prereq: 2.151 or permission of instructor
G (Fall)
3-0-9 units

Introduction to robotics and learning in machines. Kinematics and dynamics of rigid body systems. Adaptive control, system identification, sparse representations. Force control, adaptive visual servoing. Task planning, teleoperation, imitation learning. Navigation. Underactuated systems, approximate optimization and control. Dynamics of learning and optimization in networks. Elements of biological planning and control. Motor primitives, entrainment, active sensing, binding models. Term projects.
J.-J. E. Slotine, H. Asada

2.168 Learning Machines
Subject meets with 2.16
Prereq: None
G (Spring)
Not offered regularly; consult department
3-0-9 units

Introduces fundamental concepts and encourages open-ended exploration of the increasingly topical intersection between artificial intelligence and the physical sciences. Energy and information, and their respective optimality conditions are used to define supervised and unsupervised learning algorithms; as well as ordinary and partial differential equations. Subsequently, physical systems with complex constitutive relationships are drawn from elasticity, biophysics, fluid mechanics, hydrodynamics, acoustics, and electromagnetics to illustrate how machine learning-inspired optimization can approximate solutions to forward and inverse problems in these domains.
G. Barbastathis

2.171 Analysis and Design of Digital Control Systems
Prereq: 2.14, 2.151, or permission of instructor
G (Fall)
3-3-6 units

A comprehensive introduction to digital control system design, reinforced with hands-on laboratory experiences. Major topics include discrete-time system theory and analytical tools; design of digital control systems via approximation from continuous time; direct discrete-time design; loop-shaping design for performance and robustness; state-space design; observers and state-feedback; quantization and other nonlinear effects; implementation issues. Laboratory experiences and design projects connect theory with practice.
D. L. Trumper

2.174[J] Advancing Mechanics and Materials via Machine Learning
Same subject as 1.121[J]
Subject meets with 1.052
Prereq: None
G (Spring)
3-0-9 units

See description under subject 1.121[J].
M. Buehler

2.177[J] Designing Virtual Worlds
Same subject as CMS.342[J]
Subject meets with 2.178[J], CMS.942[J]
Prereq: None
U (Fall)
4-2-6 units

Three primary areas of focus are: creating new Virtual Reality experiences; mapping the state of emerging tools; and hosting guests - leaders in the VR/XR community, who serve as coaches for projects. Students have significant leeway to customize their own learning environment. As the field is rapidly evolving, each semester focuses on a new aspect of virtual worlds, based on the current state of innovations. Students work in teams of interdisciplinary peers from Berklee College of Music and Harvard University. Students taking graduate version complete additional assignments.
K. Zolot

2.178[J] Designing Virtual Worlds
Same subject as CMS.942[J]
Subject meets with 2.177[J], CMS.342[J]
Prereq: None
G (Fall)
4-2-6 units

Three primary areas of focus are: creating new Virtual Reality experiences; mapping the state of emerging tools; and hosting guests - leaders in the VR/XR community, who serve as coaches for projects. Students have significant leeway to customize their own learning environment. As the field is rapidly evolving, each semester focuses on a new aspect of virtual worlds, based on the current state of innovations. Students work in teams of interdisciplinary peers from Berklee College of Music and Harvard University. Students taking graduate version complete additional assignments.
K. Zolot

2.18 Biomolecular Feedback Systems
Subject meets with 2.180
Prereq: Biology (GIR), 18.03, or permission of instructor
G (Spring)
3-0-9 units

Comprehensive introduction to dynamics and control of biomolecular systems with emphasis on design/analysis techniques from control theory. Provides a review of biology concepts, regulation mechanisms, and models. Covers basic enabling technologies, engineering principles for designing biological functions, modular design techniques, and design limitations. Students taking graduate version complete additional assignments.
D. Del Vecchio, R. Weiss

2.180 Biomolecular Feedback Systems
Subject meets with 2.18
Prereq: Biology (GIR), 18.03, or permission of instructor
U (Spring)
3-0-9 units

Comprehensive introduction to dynamics and control of biomolecular systems with emphasis on design/analysis techniques from control theory. Provides a review of biology concepts, regulation mechanisms, and models. Covers basic enabling technologies, engineering principles for designing biological functions, modular design techniques, and design limitations. Students taking graduate version complete additional assignments.
D. Del Vecchio

2.183[J] Biomechanics and Neural Control of Movement
Same subject as 9.34[J]
Subject meets with 2.184
Prereq: 2.004 or permission of instructor
G (Spring)
3-0-9 units

Presents a quantitative description of how biomechanical and neural factors interact in human sensory-motor behavior. Students survey recent literature on how motor behavior is controlled, comparing biological and robotic approaches to similar tasks. Topics may include a review of relevant neural, muscular and skeletal physiology, neural feedback and "equilibrium-point" theories, co-contraction strategies, impedance control, kinematic redundancy, optimization, intermittency, contact tasks and tool use. Students taking graduate version complete additional assignments.
N. Hogan

2.184 Biomechanics and Neural Control of Movement
Subject meets with 2.183[J], 9.34[J]
Prereq: 2.004 or permission of instructor
U (Spring)
3-0-9 units

Presents a quantitative description of how biomechanical and neural factors interact in human sensory-motor behavior. Students survey recent literature on how motor behavior is controlled, comparing biological and robotic approaches to similar tasks. Topics may include a review of relevant neural, muscular and skeletal physiology, neural feedback and "equilibrium-point" theories, co-contraction strategies, impedance control, kinematic redundancy, optimization, intermittency, contact tasks and tool use. Students taking graduate version complete additional assignments.
N. Hogan

Fluid Mechanics and Combustion

2.20 Marine Hydrodynamics
Prereq: 1.060, 2.006, 2.016, or 2.06
G (Fall)
4-1-7 units

The fundamentals of fluid mechanics are developed in the context of naval architecture and ocean science and engineering. Transport theorem and conservation principles. Navier-Stokes' equation. Dimensional analysis. Ideal and potential flows. Vorticity and Kelvin's theorem. Hydrodynamic forces in potential flow, D'Alembert's paradox, added-mass, slender-body theory. Viscous-fluid flow, laminar and turbulent boundary layers. Model testing, scaling laws. Application of potential theory to surface waves, energy transport, wave/body forces. Linearized theory of lifting surfaces. Experimental project in the towing tank or propeller tunnel.
D. K. P. Yue

2.22 Design Principles for Ocean Vehicles
Subject meets with 2.121, 2.122
Prereq: 2.20
G (Spring)
3-1-8 units

Design tools for analysis of linear systems and random processes related to ocean vehicles; description of ocean environment including random waves, ocean wave spectra and their selection; short-term and long-term wave statistics; and ocean currents. Advanced hydrodynamics for design of ocean vehicles and offshore structures, including wave forces on towed and moored structures; inertia vs. drag-dominated flows; vortex induced vibrations (VIV) of offshore structures; ship seakeeping and sensitivity of seakeeping performance. Design exercises in application of principles. Laboratory exercises in seakeeping and VIV at model scale.
N. M. Patrikalakis, T. P. Sapsis, M. S. Triantafyllou

2.23 Hydrofoils and Propellers
Prereq: 2.20 and 18.085
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Reviews the theory and design of hydrofoil sections; lifting and thickness problems for sub-cavitating sections and unsteady flow problems. Covers lifting line and lifting surface theory with applications to hydrofoil craft, rudder, control surface, propeller and wind turbine rotor design. Topics include propeller lifting line and lifting surface theory; wake adapted propellers, steady and unsteady propeller thrust and torque; waterjets; performance analysis and design of wind turbine rotors. Presents numerical principles of vortex lattice and lifting surface panel methods. Projects illustrate the development of theoretical and computational methods for lifting, propulsion and wind turbine applications.
P. D. Sclavounos

2.24[J] Seakeeping of Ships and Offshore Energy Systems
Same subject as 1.692[J]
Prereq: 2.20 and 18.085
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
4-0-8 units

Surface wave theory, conservation laws and boundary conditions, properties of regular surface waves and random ocean waves. Linearized theory of floating body dynamics, kinematic and dynamic free surface conditions, body boundary conditions. Simple harmonic motions. Diffraction and radiation problems, added mass and damping matrices. General reciprocity identities on diffraction and radiation. Ship wave resistance theory, Kelvin wake physics, ship seakeeping in regular and random waves. Discusses point wave energy absorbers, beam sea and head-sea devises, oscillating water column device and Well's turbine. Discusses offshore floating energy systems and their interaction with ambient waves, current and wind, including oil and gas platforms, liquefied natural gas (LNG) vessels and floating wind turbines. Homework drawn from real-world applications.
P. D. Sclavounos

2.25 Fluid Mechanics
Prereq: 2.006 or 2.06; *Coreq: 18.075 or 18.085*
G (Fall)
4-0-8 units

Survey of principal concepts and methods of fluid dynamics. Mass conservation, momentum, and energy equations for continua. Navier-Stokes equation for viscous flows. Similarity and dimensional analysis. Lubrication theory. Boundary layers and separation. Circulation and vorticity theorems. Potential flow. Introduction to turbulence. Lift and drag. Surface tension and surface tension driven flows.
A. F. Ghoniem, A. E. Hosoi, G. H. McKinley, A. T. Patera

2.250[J] Fluids and Diseases
Same subject as 1.631[J], HST.537[J]
Subject meets with 1.063
Prereq: None
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-3-6 units

See description under subject 1.631[J].
L. Bourouiba

2.26[J] Advanced Fluid Dynamics
Same subject as 1.63[J]
Prereq: 18.085 and (2.25 or permission of instructor)
G (Spring)
Not offered regularly; consult department
4-0-8 units

Fundamentals of fluid dynamics intrinsic to natural physical phenomena and/or engineering processes. Discusses a range of topics and advanced problem-solving techniques. Sample topics include brief review of basic laws of fluid motion, scaling and approximations, creeping flows, boundary layers in high-speed flows, steady and transient, similarity method of solution, buoyancy-driven convection in porous media, dispersion in steady or oscillatory flows, physics and mathematics of linearized instability, effects of shear and stratification. In alternate years, two of the following modules will be offered: I: Geophysical Fluid Dynamics of Coastal Waters, II: Capillary Phenomena, III: Non-Newtonian Fluids, IV: Flagellar Swimming.
T. R. Akylas, G. H. McKinley, R. Stocker

2.28 Fundamentals and Applications of Combustion
Prereq: 2.006 or (2.051 and 2.06)
G (Fall)
3-0-9 units

Fundamentals and modeling of reacting gas dynamics and combustion using analytical and numerical methods. Conservation equations of reacting flows. Multi-species transport, chemical thermodynamics and chemical kinetics. Non-equilibrium flow. Detonation and reacting boundary layers. Ignition, flammability, and extinction. Premixed and diffusion flames. Combustion instabilities. Supersonic combustion. Turbulent combustion. Liquid and solid burning. Fire, safety, and environmental impact. Applications to power and propulsion.
A. F. Ghoniem

2.29 Numerical Fluid Mechanics
Subject meets with 2.290
Prereq: 18.075 and (2.006, 2.016, 2.06, 2.20, or 2.25)
G (Spring)
Not offered regularly; consult department
4-0-8 units

Introduction to numerical methods and MATLAB: errors, condition numbers and roots of equations. Navier-Stokes. Direct and iterative methods for linear systems. Finite differences for elliptic, parabolic and hyperbolic equations. Fourier decomposition, error analysis and stability. High-order and compact finite-differences. Finite volume methods. Time marching methods. Navier-Stokes solvers. Grid generation. Finite volumes on complex geometries. Finite element methods. Spectral methods. Boundary element and panel methods. Turbulent flows. Boundary layers. Lagrangian Coherent Structures. Includes a final research project. Students taking graduate version complete additional assignments.
P. F. J. Lermusiaux

2.290 Numerical Fluid Mechanics
Subject meets with 2.29
Prereq: 2.005
U (Spring)
Not offered regularly; consult department
4-0-8 units

Introduction to numerical methods and MATLAB: errors, condition numbers and roots of equations. Navier-Stokes. Direct and iterative methods for linear systems. Finite differences for elliptic, parabolic and hyperbolic equations. Fourier decomposition, error analysis and stability. High-order and compact finite-differences. Finite volume methods. Time marching methods. Navier-Stokes solvers. Grid generation. Finite volumes on complex geometries. Finite element methods. Spectral methods. Boundary element and panel methods. Turbulent flows. Boundary layers. Lagrangian Coherent Structures. Includes a final research project. Students taking graduate version complete additional assignments.
P. Lermusiaux

2.341[J] Macromolecular Hydrodynamics
Same subject as 10.531[J]
Prereq: 2.25, 10.301, or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-6 units

Physical phenomena in polymeric liquids undergoing deformation and flow. Kinematics and material functions for complex fluids; techniques of viscometry, rheometry; and linear viscoelastic measurements for polymeric fluids. Generalized Newtonian fluids. Continuum mechnanics, frame invariance, and convected derivatives for finite strain viscoelasticity. Differential and integral constitutive equations for viscoelastic fluids. Analytical solutions to isothermal and non-isothermal flow problems; the roles of non-Newtonian viscosity, linear viscoelasticity, normal stresses, elastic recoil, stress relaxation in processing flows. Introduction to molecular theories for dynamics of polymeric fluids. (Extensive class project and presentation required instead of a final exam).
R. C. Armstrong, G. H. McKinley

MEMS and Nanotechnology

2.37 Fundamentals of Nanoengineering
Subject meets with 2.370
Prereq: Permission of instructor
G (Spring)
3-0-9 units

Presents the fundamentals of molecular modeling in engineering in the context of nanoscale mechanical engineering applications. Statistical mechanics and its connection to engineering thermodynamics. Molecular origin and limitations of macroscopic descriptions and constitutive relations for equilibrium and non-equilibrium behavior. Introduction to molecular simulation, solid-state physics and electrokinetic phenomena. Discusses molecular approaches to modern nanoscale engineering problems. Graduate students are required to complete additional assignments with stronger analytical content.
N. G. Hadjiconstantinou

2.370 Fundamentals of Nanoengineering
Subject meets with 2.37
Prereq: Chemistry (GIR) and 2.001
U (Spring)
3-0-9 units

Presents the fundamentals of molecular modeling in engineering in the context of nanoscale mechanical engineering applications. Statistical mechanics and its connection to engineering thermodynamics. Molecular origin and limitations of macroscopic descriptions and constitutive relations for equilibrium and non-equilibrium behavior. Introduction to molecular simulation, solid-state physics and electrokinetic phenomena. Discusses molecular approaches to modern nanoscale engineering problems. Graduate students are required to complete additional assignments with stronger analytical content.
N. G. Hadjiconstantinou

2.391[J] Nanostructure Fabrication
Same subject as 6.6600[J]
Prereq: 2.710, 6.2370, 6.2600[J], or permission of instructor
G (Spring)
4-0-8 units

See description under subject 6.6600[J].
K. K. Berggren

Thermodynamics

2.42 General Thermodynamics
Prereq: Permission of instructor
G (Fall)
3-0-9 units

General foundations of thermodynamics from an entropy point of view, entropy generation and transfer in complex systems. Definitions of work, energy, stable equilibrium, available energy, entropy, thermodynamic potential, and interactions other than work (nonwork, heat, mass transfer). Applications to properties of materials, bulk flow, energy conversion, chemical equilibrium, combustion, and industrial manufacturing.
J. Brisson

2.43 Advanced Thermodynamics
Prereq: 2.42 or permission of instructor
G (Spring)
4-0-8 units

<p class="xmsolistparagraph">Self-contained concise review of general thermodynamics concepts, multicomponent equilibrium properties, chemical equilibrium, electrochemical potentials, and chemical kinetics, as needed to introduce the methods of nonequilibrium thermodynamics and to provide a unified understanding of phase equilibria, transport and nonequilibrium phenomena useful for future energy and climate engineering technologies. Applications include: second-law efficiencies and methods to allocate primary energy consumptions and CO_2 emissions in cogeneration and hybrid power systems, minimum work of separation, maximum work of mixing, osmotic pressure and membrane equilibria, metastable states, spinodal decomposition, Onsager's near-equilibrium reciprocity in thermodiffusive, thermoelectric, and electrokinetic cross effects.
G. P. Beretta

Heat and Mass Transfer

2.500 Desalination and Water Purification
Prereq: 1.020, 2.006, 10.302, (2.051 and 2.06), or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Introduces the fundamental science and technology of desalinating water to overcome water scarcity and ensure sustainable water supplies. Covers basic water chemistry, flash evaporation, reverse osmosis and membrane engineering, electrodialysis, nanofiltration, solar desalination, energy efficiency of desalination systems, fouling and scaling, environmental impacts, and economics of desalination systems. Open to upper-class undergraduates.
J. H. Lienhard, M. Balaban

2.51 Intermediate Heat and Mass Transfer
Prereq: (2.005 and 18.03) or permission of instructor
U (Fall)
Not offered regularly; consult department
3-0-9 units

Covers conduction (governing equations and boundary conditions, steady and unsteady heat transfer, resistance concept); laminar and turbulent convection (forced-convection and natural-convection boundary layers, external flows); radiation (blackbody and graybody exchange, spectral and solar radiation); coupled conduction, convection, radiation problems; synthesis of analytical, computational, and experimental techniques; and mass transfer at low rates, evaporation.
J. H. Lienhard, A. T. Patera, E. N. Wang

2.52[J] Modeling and Approximation of Thermal Processes
Same subject as 4.424[J]
Prereq: 2.51
G (Fall)
Not offered regularly; consult department
3-0-9 units

Provides instruction on how to model thermal transport processes in typical engineering systems such as those found in manufacturing, machinery, and energy technologies. Successive modules cover basic modeling tactics for particular modes of transport, including steady and unsteady heat conduction, convection, multiphase flow processes, and thermal radiation. Includes a creative design project executed by the students.
L. R. Glicksman

2.55 Advanced Heat and Mass Transfer
Prereq: 2.51
G (Spring)
4-0-8 units

Advanced treatment of fundamental aspects of heat and mass transport. Covers topics such as diffusion kinetics, conservation laws, laminar and turbulent convection, mass transfer including phase change or heterogeneous reactions, and basic thermal radiation. Problems and examples include theory and applications drawn from a spectrum of engineering design and manufacturing problems.
J. H. Lienhard

2.57 Nano-to-Macro Transport Processes
Subject meets with 2.570
Prereq: 2.005, 2.051, or permission of instructor
G (Fall)
3-0-9 units

Parallel treatments of photons, electrons, phonons, and molecules as energy carriers; aiming at a fundamental understanding of descriptive tools for energy and heat transport processes, from nanoscale to macroscale. Topics include energy levels; statistical behavior and internal energy; energy transport in the forms of waves and particles; scattering and heat generation processes; Boltzmann equation and derivation of classical laws; and deviation from classical laws at nanoscale and their appropriate descriptions. Applications in nanotechnology and microtechnology. Students taking the graduate version complete additional assignments.
G. Chen

2.570 Nano-to-Macro Transport Processes
Subject meets with 2.57
Prereq: 2.005, 2.051, or permission of instructor
U (Fall)
3-0-9 units

Parallel treatments of photons, electrons, phonons, and molecules as energy carriers; aiming at a fundamental understanding of descriptive tools for energy and heat transport processes, from nanoscale to macroscale. Topics include energy levels; statistical behavior and internal energy; energy transport in the forms of waves and particles; scattering and heat generation processes; Boltzmann equation and derivation of classical laws; and deviation from classical laws at nanoscale and their appropriate descriptions. Applications in nanotechnology and microtechnology. Students taking the graduate version complete additional assignments.
G. Chen

2.58 Radiative Transfer
Prereq: 2.51, 10.302, or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Principles of thermal radiation and their application to engineering heat and photon transfer problems. Quantum and classical models of radiative properties of materials, electromagnetic wave theory for thermal radiation, radiative transfer in absorbing, emitting, and scattering media, and coherent laser radiation. Applications cover laser-material interactions, imaging, infrared instrumentation, global warming, semiconductor manufacturing, combustion, furnaces, and high temperature processing.
G. Chen

2.59[J] Thermal Hydraulics in Power Technology
Same subject as 10.536[J], 22.313[J]
Prereq: 2.006, 10.302, 22.312, or permission of instructor
G (Fall)
3-2-7 units

See description under subject 22.313[J].
E. Baglietto, M. Bucci

Energy and Power Systems

2.60[J] Fundamentals of Advanced Energy Conversion
Same subject as 10.390[J]
Subject meets with 2.62[J], 10.392[J], 22.40[J]
Prereq: 2.006, (2.051 and 2.06), or permission of instructor
U (Spring)
4-0-8 units

Fundamentals of thermodynamics, chemistry, and transport applied to energy systems. Analysis of energy conversion and storage in thermal, mechanical, chemical, and electrochemical processes in power and transportation systems, with emphasis on efficiency, performance, and environmental impact. Applications to fuel reforming and alternative fuels, hydrogen, fuel cells and batteries, combustion, catalysis, combined and hybrid power cycles using fossil, nuclear and renewable resources. CO_2 separation and capture. Biomass energy. Students taking graduate version complete additional assignments.
A. F. Ghoniem, W. Green

2.603 Fundamentals of Smart and Resilient Grids
Prereq: 2.003[J]
U (Fall)
Not offered regularly; consult department
4-0-8 units

Introduces the fundamentals of power system structure, operation and control. Emphasizes the challenges and opportunities for integration of new technologies: photovoltaic, wind, electric storage, demand response, synchrophasor measurements. Introduces the basics of power system modeling and analysis. Presents the basic phenomena of voltage and frequency stability as well technological and regulatory constraints on system operation. Describes both the common and emerging automatic control systems and operator decision-making policies. Relies on a combination of traditional lectures, homework assignments, and group projects. Students taking graduate version complete additional assignments.
K. Turitsyn

2.61 Internal Combustion Engines
Prereq: 2.006
G (Spring)
Not offered regularly; consult department
3-1-8 units

Fundamentals of how the design and operation of internal combustion engines affect their performance, efficiency, fuel requirements, and environmental impact. Study of fluid flow, thermodynamics, combustion, heat transfer and friction phenomena, and fuel properties, relevant to engine power, efficiency, and emissions. Examination of design features and operating characteristics of different types of internal combustion engines: spark-ignition, diesel, stratified-charge, and mixed-cycle engines. Engine Laboratory project. For graduate and senior undergraduate students.
W. K. Cheng

2.611 Marine Power and Propulsion
Subject meets with 2.612
Prereq: 2.005
G (Fall)
4-0-8 units

Selection and evaluation of commercial and naval ship power and propulsion systems. Analysis of propulsors, prime mover thermodynamic cycles, propeller-engine matching. Propeller selection, waterjet analysis, review of alternative propulsors; thermodynamic analyses of Rankine, Brayton, Diesel, and Combined cycles, reduction gears and integrated electric drive. Battery operated vehicles, fuel cells. Term project requires analysis of alternatives in propulsion plant design for given physical, performance, and economic constraints. Graduate students complete different assignments and exams.
J. Harbour, M. S. Triantafyllou, R. S. McCord

2.612 Marine Power and Propulsion
Subject meets with 2.611
Prereq: 2.005
U (Fall)
4-0-8 units

Selection and evaluation of commercial and naval ship power and propulsion systems. Analysis of propulsors, prime mover thermodynamic cycles, propeller-engine matching. Propeller selection, waterjet analysis, review of alternative propulsors; thermodynamic analyses of Rankine, Brayton, Diesel, and Combined cycles, reduction gears and integrated electric drive. Battery operated vehicles, fuel cells. Term project requires analysis of alternatives in propulsion plant design for given physical, performance, and economic constraints. Graduate students complete different assignments and exams.
J. Harbour, M. S. Triantafyllou, R. S. McCord

2.62[J] Fundamentals of Advanced Energy Conversion
Same subject as 10.392[J], 22.40[J]
Subject meets with 2.60[J], 10.390[J]
Prereq: 2.006, (2.051 and 2.06), or permission of instructor
G (Spring)
4-0-8 units

Fundamentals of thermodynamics, chemistry, and transport applied to energy systems. Analysis of energy conversion and storage in thermal, mechanical, chemical, and electrochemical processes in power and transportation systems, with emphasis on efficiency, performance and environmental impact. Applications to fuel reforming and alternative fuels, hydrogen, fuel cells and batteries, combustion, catalysis, combined and hybrid power cycles using fossil, nuclear and renewable resources. CO_2 separation and capture. Biomass energy. Meets with 2.60[J] when offered concurrently; students taking the graduate version complete additional assignments.
A. F. Ghoniem, W. Green

2.625[J] Electrochemical Energy Conversion and Storage: Fundamentals, Materials and Applications
Same subject as 10.625[J]
Prereq: 2.005, 3.046, 3.53, 10.40, (2.051 and 2.06), or permission of instructor
G (Fall)
Not offered regularly; consult department
4-0-8 units

Fundamental concepts, tools, and applications in electrochemical science and engineering. Introduces thermodynamics, kinetics and transport of electrochemical reactions. Describes how materials structure and properties affect electrochemical behavior of particular applications, for instance in lithium rechargeable batteries, electrochemical capacitors, fuel cells, photo electrochemical cells, and electrolytic cells. Discusses state-of-the-art electrochemical energy technologies for portable electronic devices, hybrid and plug-in vehicles, electrical vehicles. Theoretical and experimental exploration of electrochemical measurement techniques in cell testing, and in bulk and interfacial transport measurements (electronic and ionic resistivity and charge transfer cross the electrode-electrolyte interface).
Y. Shao-Horn

2.626 Fundamentals of Photovoltaics
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
4-0-8 units

Fundamentals of photoelectric conversion: charge excitation, conduction, separation, and collection. Studies commercial and emerging photovoltaic technologies. Cross-cutting themes include conversion efficiencies, loss mechanisms, characterization, manufacturing, systems, reliability, life-cycle analysis, and risk analysis. Photovoltaic technology evolution in the context of markets, policies, society, and environment. Graduate students complete additional work.
T. Buonassisi

2.627 Fundamentals of Photovoltaics
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
4-0-8 units

Fundamentals of photoelectric conversion: charge excitation, conduction, separation, and collection. Studies commercial and emerging photovoltaic technologies. Cross-cutting themes include conversion efficiencies, loss mechanisms, characterization, manufacturing, systems, reliability, life-cycle analysis, and risk analysis. Photovoltaic technology evolution in the context of markets, policies, society, and environment. Graduate students complete additional work.
T. Buonassisi

2.630 Interfacial Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
3-0-9 units

Interfacial interactions are ubiquitous in many industries including energy, water, agriculture, medical, transportation, and consumer products. Transport processes are typically limited by interfaces. Addresses how interfacial properties (eg., chemistry, morphology, thermal, electrical) can be engineered for significant efficiency enhancements. Topics include surface tension and wetting phenomena, thermodynamics of interfaces, surface chemistry and morphology, nonwetting, slippery, and superwetting surfaces, charged interfaces and electric double layers, intermolecular forces, Van der Waals and double-layer forces, DLVO theory, electrowetting and electro-osmotic flows, electrochemical bubbles, surfactants, phase transitions, and bio-interfaces. Manufacturing approaches, entrepreneurial efforts to translate technologies to markets, guest lectures and start-up company tours provide real-world exposure. Anticipated enrollment is 15-20.
K. Varanasi

2.65[J] Sustainable Energy
Same subject as 1.818[J], 10.391[J], 11.371[J], 22.811[J]
Subject meets with 2.650[J], 10.291[J], 22.081[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-1-8 units

See description under subject 22.811[J].
M. W. Golay

2.650[J] Introduction to Sustainable Energy
Same subject as 10.291[J], 22.081[J]
Subject meets with 1.818[J], 2.65[J], 10.391[J], 11.371[J], 22.811[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-1-8 units

See description under subject 22.081[J]. Limited to juniors and seniors.
M. W. Golay

2.651[J] Introduction to Energy in Global Development
Same subject as EC.711[J]
Subject meets with EC.791
Prereq: None
U (Spring)
3-2-7 units

See description under subject EC.711[J]. Enrollment limited by lottery; must attend first class session.
D. Sweeney, S. Hsu

2.652[J] Applications of Energy in Global Development
Same subject as EC.712[J]
Subject meets with EC.782
Prereq: None
U (Fall)
4-0-8 units

See description under subject EC.712[J]. Limited to 20; preference to students who have taken EC.711[J].
D. Sweeney, Staff

Experimental Engineering

2.670 Mechanical Engineering Tools
Prereq: None
U (Fall, IAP, Spring)
0-1-2 units

Introduces the fundamentals of machine tools use and fabrication techniques. Students work with a variety of machine tools including the bandsaw, milling machine, and lathe. Mechanical Engineering students are advised to take this subject in the first IAP after declaring their major. Enrollment may be limited due to laboratory capacity. Preference to Course 2 majors and minors.
M. Culpepper

2.671 Measurement and Instrumentation
Prereq: Physics II (GIR), 2.001, 2.003[J], and 2.086
U (Fall, Spring)
3-3-6 units. Institute LAB

Introduces fundamental concepts and experimental techniques for observation and measurement of physical variables such as force and motion, liquid and gas properties, physiological parameters, and measurements of light, sound, electrical quantities, and temperature. Emphasizes mathematical techniques including uncertainty analysis and statistics, Fourier analysis, frequency response, and correlation functions. Uses engineering knowledge to select instruments and design experimental methods to obtain and interpret meaningful data. Guided learning during lab experiments promotes independent experiment design and measurements performed outside the lab in the semester-long "Go Forth and Measure" project. Advances students' ability to critically read, evaluate, and extract specific technical meaning from information in a variety of media, and provides extensive instruction and practice in written, graphical, and oral communication. Enrollment limited.
I. W. Hunter, M. Kolle, B. Hughey

2.673[J] Instrumentation and Measurement for Biological Systems
Same subject as 20.309[J]
Subject meets with 20.409
Prereq: (Biology (GIR), Physics II (GIR), 6.100B, and 18.03) or permission of instructor
U (Fall, Spring)
3-6-3 units

See description under subject 20.309[J]. Enrollment limited; preference to Course 20 undergraduates.
P. Blainey, S. Manalis, E. Frank, S. Wasserman, J. Bagnall, E. Boyden, P. So

2.674 Introduction to Micro/Nano Engineering Laboratory
Prereq: Physics II (GIR) or permission of instructor
U (Spring)
1-3-2 units
Credit cannot also be received for 2.675, 2.676

Presents concepts, ideas, and enabling tools for nanoengineering through experiential lab modules, which include microfluidics, microelectromechanical systems (MEMS), and nanomaterials and nanoimaging tools such as scanning electron microscopy (SEM), transmission electron microscopy (TEM), and atomic-force microscopy (AFM). Provides knowledge and experience via building, observing and manipulating micro- and nanoscale structures. Exposes students to fluid, thermal, and dynamic systems at small scales. Enrollment limited; preference to Course 2 and 2-A majors and minors.
N. Fang, S. G. Kim, R. Karnik, M. Kolle, J. Kim

2.675 Micro/Nano Engineering Laboratory
Subject meets with 2.676
Prereq: 2.25 and (6.777 or permission of instructor)
G (Fall)
2-3-7 units
Credit cannot also be received for 2.674

Covers advanced nanoengineering via practical lab modules in connection with classical fluid dynamics, mechanics, thermodynamics, and material physics. Labs include microfluidic systems, microelectromechanical systems (MEMS), emerging nanomaterials such as graphene, carbon nanotubes (CNTs), and nanoimaging tools. Student teams lead an experimental term project that uses the tools and knowledge acquired through the lab modules and experimental work, and culminates in a report and presentation. Recitations cover idea development, experiment design, planning and execution, and analysis of results pertinent to the project. Enrollment limited.
B. Comeau, J. Kim

2.676 Micro/Nano Engineering Laboratory
Subject meets with 2.675
Prereq: 2.001, 2.003[J], 2.671, and *Coreq: (2.005 or (2.051 and 2.06))*; or permission of instructor
U (Fall)
2-3-7 units
Credit cannot also be received for 2.674

Studies advanced nanoengineering via experiental lab modules with classical fluid dynamics, mechanics, thermodynamics, and materials science. Lab modules include microfluidic systems; microelectromechanical systems (MEMS); emerging nanomaterials, such as graphene and carbon nanotubes (CNTs); and nanoimaging tools. Recitation develops in-depth knowledge and understanding of physical phenomena observed in the lab through quantitative analysis. Students have the option to engage in term projects led by students taking 2.675. Enrollment limited; preference to Course 2 and 2-OE majors and minors.
B. Comeau, J. Kim

2.677 Design and Experimentation for Ocean Engineering
Prereq: 2.00A and 2.086; *Coreq: 2.016 or permission of instructor*
U (Fall)
Not offered regularly; consult department
0-3-3 units

Design and experimental observation for ocean engineering systems focusing on the fundamentals of ocean wave propagation, ocean wave spectra and wave dispersion, cavitation, added mass, acoustic sound propagation in water, sea loads on offshore structures, design of experiments for ship model testing, fish-like swimming propulsion, propellers, and ocean energy harvesting. Emphasizes fundamentals of data analysis of signals from random environments using Fourier transforms, noise filtering, statistics and error analysis using MATLAB. Students carry out experiential laboratory exercises in various Ocean Engineering laboratories on campus, including short labs and demos, longer exercises with written reports, and a final experimental design project. Enrollment may be limited due to laboratory capacity.
A. H. Techet

2.678 Electronics for Mechanical Systems
Prereq: Physics II (GIR)
U (Fall, Spring)
2-2-2 units

Practical introduction to the fundamentals of electronics in the context of electro-mechanical systems, with emphasis on experimentation and project work in basic electronics. Laboratory exercises include the design and construction of simple electronic devices, such as power supplies, amplifiers, op-amp circuits, switched mode dc-dc converters, and dc motor drivers. Surveys embedded microcontrollers as system elements. Laboratory sessions stress the understanding of electronic circuits at the component level, but also point out the modern approach of system integration using commercial modules and specialized integrated circuits. Enrollment may be limited due to laboratory capacity; preference to Course 2 majors and minors.
S. Banzaert, J. Leonard, M. Kolle, D. Trumper

2.679 Electronics for Mechanical Systems II
Prereq: 2.086, 2.678, and 18.03
U (Spring)
2-3-1 units

Extends the concepts and techniques developed in 2.678 to include complex systems and modeling of real-world elements with a strong emphasis on lab experimentation and independent project work. Topics include sampling theory, energy storage, embedded mobile systems, autonomous navigation, printed circuit board design, system integration, and machine vision. Enrollment may be limited; preference to Course 2 majors.
S. Banzaert, J. Leonard

Oceanographic Engineering and Acoustics

2.680 Unmanned Marine Vehicle Autonomy, Sensing, and Communication
Prereq: Permission of instructor
G (Spring)
2-6-4 units

Focuses on software and algorithms for autonomous decision making (autonomy) by underwater vehicles operating in ocean environments. Discusses how autonomous marine vehicles (UMVs) adapt to the environment for improved sensing performance. Covers sensors for acoustic, biological and chemical sensing and their integration with the autonomy system for environmentally adaptive undersea mapping and observation. Introduces students to the underwater acoustic communication environment and various options for undersea navigation, highlighting their relevance to the operation of collaborative undersea networks for environmental sensing. Labs involve the use of the MOOP-IvP autonomy software for the development of integrated sensing, modeling and control solutions. Solutions modeled in simulation environments and include field tests with small autonomous surface and underwater vehicles operated on the Charles River. Limited enrollment.
H. Schmidt, J. J. Leonard, M. Benjamin

2.681 Environmental Ocean Acoustics
Prereq: 2.066, 18.075, or permission of instructor
G (Fall)
3-0-9 units

Fundamentals of underwater sound, and its application to mapping and surveillance in an ocean environment. Wave equations for fluid and elastic media. Reflection and transmission of sound at plane interfaces. Wave theory representation of acoustic source radiation and propagation in shallow and deep ocean waveguides. Interaction of underwater sound with elastic waves in the seabed and an Arctic ice cover, including effects of porosity and anisotropy. Numerical modeling of the propagation of underwater sound, including spectral methods, normal mode theory, and the parabolic equation method, for laterally homogeneous and inhomogeneous environments. Doppler effects. Effects of oceanographic variability and fluctuation - spatial and temporal coherence. Generation and propagation of ocean ambient noise. Modeling and simulation of signals and noise in traditional sonar systems, as well as modern, distributed, autonomous acoustic surveillance systems.
H. Schmidt

2.682 Acoustical Oceanography
Prereq: 2.681
G (Spring)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

Provides brief overview of what important current research topics are in oceanography (physical, geological, and biological) and how acoustics can be used as a tool to address them. Three typical examples are climate, bottom geology, and marine mammal behavior. Addresses the acoustic inverse problem, reviewing inverse methods (linear and nonlinear) and the combination of acoustical methods with other measurements as an integrated system. Concentrates on specific case studies, taken from current research journals.
J. F. Lynch, Woods Hole Staff

2.683 Marine Bioacoustics and Geoacoustics
Prereq: 2.681
G (Spring)
3-0-9 units
Can be repeated for credit.

Both active and passive acoustic methods of measuring marine organisms, the seafloor, and their interactions are reviewed. Acoustic methods of detecting, observing, and quantifying marine biological organisms are described, as are acoustic methods of measuring geological properties of the seafloor, including depth, and surficial and volumetric composition. Interactions are also described, including effects of biological scatterers on geological measurements, and effects of seafloor scattering on measurements of biological scatterers on, in, or immediately above the seafloor. Methods of determining small-scale material properties of organisms and the seafloor are outlined. Operational methods are emphasized, and corresponding measurement theory is described. Case studies are used in illustration. Principles of acoustic-system calibration are elaborated.
K. G. Foote, Woods Hole Staff

2.684 Wave Scattering by Rough Surfaces and Inhomogeneous Media
Prereq: 2.066 or permission of instrctor
G (Fall)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

An advanced-level subject designed to give students a working knowledge of current techniques in this area. Material is presented principally in the context of ocean acoustics, but can be used in other acoustic and electromagnetic applications. Includes fundamentals of wave propagation through, and/or scattering by: random media, extended coherent structures, rough surfaces, and discrete scatterers.
T. K. Stanton, A. C. Lavery, Woods Hole Staff

2.687 Time Series Analysis and System Identification
Prereq: 6.3010 and 18.06
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

Covers matched filtering, power spectral (PSD) estimation, and adaptive signal processing / system identification algorithms. Algorithm development is framed as an optimization problem, and optimal and approximate solutions are described. Reviews time-varying systems, first and second moment representations of stochastic processes, and state-space models. Also covers algorithm derivation, performance analysis, and robustness to modeling errors. Algorithms for PSD estimation, the LMS and RLS algorithms, and the Kalman Filter are treated in detail.
J. C. Preisig, Woods Hole Staff

2.688 Principles of Oceanographic Instrument Systems -- Sensors and Measurements
Prereq: 2.671 and 18.075
G (Fall)
3-3-6 units

Introduces theoretical and practical principles of design of oceanographic sensor systems. Transducer characteristics for acoustic, current, temperature, pressure, electric, magnetic, gravity, salinity, velocity, heat flow, and optical devices. Limitations on these devices imposed by ocean environment. Signal conditioning and recording; noise, sensitivity, and sampling limitations; standards. Principles of state-of-the-art systems being used in physical oceanography, geophysics, submersibles, acoustics discussed in lectures by experts in these areas. Day cruises in local waters during which the students will prepare, deploy and analyze observations from standard oceanographic instruments constitute the lab work for this subject.
H. Singh, R. Geyer, A. Michel

2.689[J] Projects in Oceanographic Engineering
Same subject as 1.699[J]
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Projects in oceanographic engineering, carried out under supervision of Woods Hole Oceanographic Institution staff. Given at Woods Hole Oceanographic Institution.
J. Preisig, Woods Hole Staff

2.690 Corrosion in Marine Engineering
Prereq: 3.012 and permission of instructor
G (Summer)
3-0-3 units

Introduction to forms of corrosion encountered in marine systems material selection, coatings and protection systems. Case studies and causal analysis developed through student presentations.
J. Page, T. Eagar

Naval Architecture

2.700 Principles of Naval Architecture
Subject meets with 2.701
Prereq: 2.002
U (Fall)
4-2-6 units

Presents principles of naval architecture, ship geometry, hydrostatics, calculation and drawing of curves of form, intact and damage stability, hull structure strength calculations and ship resistance. Introduces computer-aided naval ship design and analysis tools. Projects include analysis of ship lines drawings, calculation of ship hydrostatic characteristics, analysis of intact and damaged stability, ship model testing, and hull structure strength calculations. Students taking graduate version complete additional assignments.
R. Bebermeyer, P. D. Sclavounos

2.701 Principles of Naval Architecture
Subject meets with 2.700
Prereq: 2.002
G (Fall)
4-2-6 units

Presents principles of naval architecture, ship geometry, hydrostatics, calculation and drawing of curves of form, intact and damage stability, hull structure strength calculations and ship resistance. Introduces computer-aided naval ship design and analysis tools. Projects include analysis of ship lines drawings, calculation of ship hydrostatic characteristics, analysis of intact and damaged stability, ship model testing, and hull structure strength calculations. Students taking graduate version complete additional assignments.
R. Bebermeyer, P. Sclavounuos

2.702 Systems Engineering and Naval Ship Design
Prereq: 2.701
G (Spring)
3-3-6 units

Introduces principles of systems engineering and ship design with an overview of naval ship design and acquisition processes, requirements setting, formulation of a systematic plan, design philosophy and constraints, formal decision making methods, selection criteria, optimization, variant analysis, trade-offs, analysis of ship design trends, risk, and cost analysis. Emphasizes the application of principles through completion of a design exercise and project.
R. Bebermeyer, A. Gillespy

2.703 Principles of Naval Ship Design
Prereq: 2.082, 2.20, 2.611, and 2.702
G (Fall)
4-2-6 units

Covers the design of surface ship platforms for naval applications. Includes topics such as hull form selection and concept design synthesis, topside and general arrangements, weight estimation, and technical feasibility analyses (including strength, stability, seakeeping, and survivability.). Practical exercises involve application of design principles and utilization of advanced computer-aided ship design tools.
J. Harbour, J. Page

2.704 Projects in Naval Ship Conversion Design
Prereq: 2.703
G (IAP, Spring)
1-6-5 units

Focuses on conversion design of a naval ship. A new mission requirement is defined, requiring significant modification to an existing ship. Involves requirements setting, design plan formulation and design philosophy, and employs formal decision-making methods. Technical aspects demonstrate feasibility and desirability. Includes formal written and verbal reports and team projects.
J. Harbour, J. Page

2.705 Projects in New Concept Naval Ship Design
Prereq: 2.704
G (Fall, Spring)
Units arranged
Can be repeated for credit.

Focus on preliminary design of a new naval ship, fulfilling a given set of mission requirements. Design plan formulation, system level trade-off studies, emphasizes achieving a balanced design and total system integration. Formal written and oral reports. Team projects extend over three terms.
R. Bebermeyer, R. Jonart

2.707 Submarine Structural Acoustics
Prereq: 2.066
G (Spring; first half of term)
Not offered regularly; consult department
2-0-4 units

Introduction to the acoustic interaction of submerged structures with the surrounding fluid. Fluid and elastic wave equations. Elastic waves in plates. Radiation and scattering from planar structures as well as curved structures such as spheres and cylinders. Acoustic imaging of structural vibrations. Students can take 2.085 in the second half of term.
H. Schmidt

2.708 Traditional Naval Architecture Design
Prereq: None
G (IAP)
Not offered regularly; consult department
2-0-1 units

Week-long intensive introduction to traditional design methods in which students hand draw a lines plan of a N. G. Herreshoff (MIT Class of 1870) design based on hull shape offsets taken from his original design model. After completing the plan, students then carve a wooden half-hull model of the boat design. Covers methods used to develop hull shape analysis data from lines plans. Provides students with instruction in safe hand tool use and how to transfer their lines to 3D in the form of their model. Limited to 15.
K. Hasselbalch, J. Harbour

Optics

2.71 Optics
Subject meets with 2.710
Prereq: (Physics II (GIR), 2.004, and 18.03) or permission of instructor
U (Fall)
3-0-9 units

Introduction to optical science with elementary engineering applications. Geometrical optics: ray-tracing, aberrations, lens design, apertures and stops, radiometry and photometry. Wave optics: basic electrodynamics, polarization, interference, wave-guiding, Fresnel and Fraunhofer diffraction, image formation, resolution, space-bandwidth product. Emphasis on analytical and numerical tools used in optical design. Graduate students are required to complete additional assignments with stronger analytical content, and an advanced design project.
G. Barbastathis, P. T. So

2.710 Optics
Subject meets with 2.71
Prereq: (Physics II (GIR), 2.004, and 18.03) or permission of instructor
G (Fall)
3-0-9 units

Introduction to optical science with elementary engineering applications. Geometrical optics: ray-tracing, aberrations, lens design, apertures and stops, radiometry and photometry. Wave optics: basic electrodynamics, polarization, interference, wave-guiding, Fresnel and Fraunhofer diffraction, image formation, resolution, space-bandwidth product. Emphasis on analytical and numerical tools used in optical design. Graduate students are required to complete additional assignments with stronger analytical content, and an advanced design project.
G. Barbastathis, P. T. So

2.715[J] Optical Microscopy and Spectroscopy for Biology and Medicine
Same subject as 20.487[J]
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Introduces the theory and the design of optical microscopy and its applications in biology and medicine. The course starts from an overview of basic optical principles allowing an understanding of microscopic image formation and common contrast modalities such as dark field, phase, and DIC. Advanced microscopy imaging techniques such as total internal reflection, confocal, and multiphoton will also be discussed. Quantitative analysis of biochemical microenvironment using spectroscopic techniques based on fluorescence, second harmonic, Raman signals will be covered. We will also provide an overview of key image processing techniques for microscopic data.
P. T. So, C. Sheppard

2.717 Optical Engineering
Prereq: 2.710 or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Theory and practice of optical methods in engineering and system design. Emphasis on diffraction, statistical optics, holography, and imaging. Provides engineering methodology skills necessary to incorporate optical components in systems serving diverse areas such as precision engineering and metrology, bio-imaging, and computing (sensors, data storage, communication in multi-processor systems). Experimental demonstrations and a design project are included.
P. T. So, G. Barbastathis

2.718 Photonic Materials
Subject meets with 2.719
Prereq: 2.003[J], 8.03, 6.2370, or permission of instructor
U (Spring)
3-0-9 units

Provides a review of Maxwell's equations and the Helmholtz wave equation. Optical devices: waveguides and cavities, phase and group velocity, causality, and scattering. Light-matter interaction in bulk, surface, and subwavelength-structured matter. Effective media, dispersion relationships, wavefronts and rays, eikonal description of light propagation, phase singularities. Transformation optics, gradient effective media. Includes description of the experimental tools for realization and measurement of photonic materials and effects. Students taking graduate version complete additional assignments.
G. Barbastathis, N. Fang

2.719 Photonic Materials
Subject meets with 2.718
Prereq: 2.003[J], 8.03, 6.2370, or permission of instructor
G (Spring)
3-0-9 units

Provides a review of Maxwell's equations and the Helmholtz wave equation. Optical devices: waveguides and cavities, phase and group velocity, causality, and scattering. Light-matter interaction in bulk, surface, and subwavelength-structured matter. Effective media, dispersion relationships, wavefronts and rays, eikonal description of light propagation, phase singularities. Transformation optics, gradient effective media. Includes description of the experimental tools for realization and measurement of photonic materials and effects. Students taking graduate version complete additional assignments.
G. Barbastathis, N. Fang

Design

2.70 FUNdaMENTALS of Precision Product Design
Subject meets with 2.77
Prereq: 2.008
U (Fall)
3-3-6 units

Examines design, selection, and combination of machine elements to produce a robust precision system. Introduces process, philosophy and physics-based principles of design to improve/enable renewable power generation, energy efficiency, and manufacturing productivity. Topics include linkages, power transmission, screws and gears, actuators, structures, joints, bearings, error apportionment, and error budgeting. Considers each topic with respect to its physics of operation, mechanics (strength, deformation, thermal effects) and accuracy, repeatability, and resolution. Includes guest lectures from practicing industry and academic leaders. Students design, build, and test a small benchtop precision machine, such as a heliostat for positioning solar PV panels or a two or three axis machine. Prior to each lecture, students review the pre-recorded detailed topic materials and then converge on what parts of the topic they want covered in extra depth in lecture. Students are assessed on their preparation for and participation in class sessions. Students taking graduate version complete additional assignments. Enrollment limited.
A. Slocum

2.77 FUNdaMENTALS of Precision Product Design
Subject meets with 2.70
Prereq: 2.008
G (Fall)
3-3-6 units

Examines design, selection, and combination of machine elements to produce a robust precision system. Introduces process, philosophy and physics-based principles of design to improve/enable renewable power generation, energy efficiency, and manufacturing productivity. Topics include linkages, power transmission, screws and gears, actuators, structures, joints, bearings, error apportionment, and error budgeting. Considers each topic with respect to its physics of operation, mechanics (strength, deformation, thermal effects) and accuracy, repeatability, and resolution. Includes guest lectures from practicing industry and academic leaders. Students design, build, and test a small benchtop precision machine, such as a heliostat for positioning solar PV panels or a two or three axis machine. Prior to each lecture, students review the pre-recorded detailed topic materials and then converge on what parts of the topic they want covered in extra depth in lecture. Students are assessed on their preparation for and participation in class sessions. Students taking graduate version complete additional assignments. Enrollment limited.
A. Slocum

2.72 Elements of Mechanical Design
Subject meets with 2.720
Prereq: 2.008 and (2.005 or 2.051); *Coreq: 2.671*
U (Spring)
3-3-6 units

Advanced study of modeling, design, integration, and best practices for use of machine elements, such as bearings, bolts, belts, flexures, and gears. Modeling and analysis is based upon rigorous application of physics, mathematics, and core mechanical engineering principles, which are reinforced via laboratory experiences and a design project in which students model, design, fabricate, and characterize a mechanical system that is relevant to a real-world application. Activities and quizzes are directly related to, and coordinated with, the project deliverables. Develops the ability to synthesize, model and fabricate a design subject to engineering constraints (e.g., cost, time, schedule). Students taking graduate version complete additional assignments. Enrollment limited.
M. L. Culpepper

2.720 Elements of Mechanical Design
Subject meets with 2.72
Prereq: Permission of instructor
G (Spring)
3-3-6 units

Advanced study of modeling, design, integration, and best practices for use of machine elements, such as bearings, bolts, belts, flexures, and gears. Modeling and analysis is based upon rigorous application of physics, mathematics, and core mechanical engineering principles, which are reinforced via laboratory experiences and a design project in which students model, design, fabricate, and characterize a mechanical system that is relevant to a real-world application. Activities and quizzes are directly related to, and coordinated with, the project deliverables. Develops the ability to synthesize, model and fabricate a design subject to engineering constraints (e.g., cost, time, schedule). Students taking graduate version complete additional assignments.
M. L. Culpepper

2.722[J] D-Lab: Design
Same subject as EC.720[J]
Prereq: 2.670 or permission of instructor
U (Spring)
3-0-9 units

See description under subject EC.720[J]. Enrollment limited by lottery; must attend first class session.
E. Squibb

2.7231[J] Introduction to Design Thinking and Innovation in Engineering
Same subject as 6.9101[J], 16.6621[J]
Prereq: None
U (Fall, Spring; partial term)
2-0-1 units

See description under subject 6.9101[J]. Enrollment limited to 25; priority to first-year students.
B. Kotelly

2.723A Design Thinking and Innovation Leadership for Engineers
Engineering School-Wide Elective Subject.
Offered under: 2.723A, 6.910A, 16.662A
Prereq: None
U (Fall, Spring; partial term)
2-0-1 units

See description under subject 6.910A.
B. Kotelly

2.723B Design Thinking and Innovation Project
Engineering School-Wide Elective Subject.
Offered under: 2.723B, 6.910B, 16.662B
Prereq: 6.910A
U (Fall, Spring; partial term)
2-0-1 units

See description under subject 6.910B.
B. Kotelly

2.729[J] D-Lab: Design for Scale
Same subject as EC.729[J]
Subject meets with 2.789[J], EC.797[J]
Prereq: None. *Coreq: 2.008*; or permission of instructor
U (Fall)
3-2-7 units

See description under subject EC.729[J].
M. Yang, M. Kenney

2.733 Engineering Systems Design
Subject meets with 2.013
Prereq: (2.001, 2.003[J], (2.005 or 2.051), and (2.00B, 2.670, or 2.678)) or permission of instructor
G (Fall)
0-6-6 units

Focuses on the design of engineering systems to satisfy stated performance, stability, and/or control requirements. Emphasizes individual initiative, application of fundamental principles, and the compromises inherent in the engineering design process. Culminates in the design of an engineering system, typically a vehicle or other complex system. Includes instruction and practice in written and oral communication through team presentation, design reviews, and written reports. Students taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity.
D. Hart

2.734 Engineering Systems Development
Subject meets with 2.014
Prereq: (2.001, 2.003[J], (2.005 or 2.051), and (2.00B, 2.670, or 2.678)) or permission of instructor
G (Spring)
0-6-6 units

Focuses on the implementation and operation of engineering systems. Emphasizes system integration and performance verification using methods of experimental inquiry. Students refine their subsystem designs and the fabrication of working prototypes. Includes experimental analysis of subperformance and comparison with physical models of performance and with design goals. component integration into the full system, with detailed analysis and operation of the complete vehicle in the laboratory and in the field. Includes written and oral reports. Students carry out formal reviews of the overall system design. Instruction and practice in oral and written communication provided. Students taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity.
D. Hart

2.737 Mechatronics
Prereq: 6.2000 and (2.14, 6.3100, or 16.30)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-5-4 units

Introduction to designing mechatronic systems, which require integration of the mechanical and electrical engineering disciplines within a unified framework. Significant laboratory-based design experiences form subject's core. Final project. Topics include: low-level interfacing of software with hardware; use of high-level graphical programming tools to implement real-time computation tasks; digital logic; analog interfacing and power amplifiers; measurement and sensing; electromagnetic and optical transducers; control of mechatronic systems. Limited to 20.
D. L. Trumper, K. Youcef-Toumi

2.739[J] Product Design and Development
Same subject as 15.783[J]
Prereq: 2.009, 15.761, 15.778, 15.814, or permission of instructor
G (Spring)
3-3-6 units

See description under subject 15.783[J]. Engineering students accepted via lottery based on WebSIS pre-registration.
S. Eppinger, M. C. Yang

2.74 Bio-inspired Robotics
Subject meets with 2.740
Prereq: 2.004 or permission of instructor
U (Fall)
3-1-8 units

Interdisciplinary approach to bio-inspired design, with emphasis on principle extraction applicable to various robotics research fields, such as robotics, prosthetics, and human assistive technologies. Focuses on three main components: biomechanics, numerical techniques that allow multi-body dynamics simulation with environmental interaction and optimization, and basic robotics techniques and implementation skills. Students integrate the components into a final robotic system project of their choosing through which they must demonstrate their understanding of dynamics and control and test hypothesized design principles. Students taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity.
S. Kim

2.740 Bio-inspired Robotics
Subject meets with 2.74
Prereq: 2.004 or permission of instructor
G (Fall)
3-3-6 units

Interdisciplinary approach to bio-inspired design, with emphasis on principle extraction applicable to various robotics research fields, such as robotics, prosthetics, and human assistive technologies. Focuses on three main components: biomechanics, numerical techniques that allow multi-body dynamics simulation with environmental interaction and optimization, and basic robotics techniques and implementation skills. Students integrate the components into a final robotic system project of their choosing through which they must demonstrate their understanding of dynamics and control and test hypothesized design principles. Students taking graduate version complete additional assignments. Enrollment may be limited due to lab capacity.
S. Kim

2.744 Product Design
Prereq: 2.009
G (Spring)
Not offered regularly; consult department
3-0-9 units

Project-centered subject addressing transformation of ideas into successful products which are properly matched to the user and the market. Students are asked to take a more complete view of a new product and to gain experience with designs judged on their aesthetics, ease of use, and sensitivities to the realities of the marketplace. Lectures on modern design process, industrial design, visual communication, form-giving, mass production, marketing, and environmentally conscious design.
D. R. Wallace

2.75[J] Medical Device Design
Same subject as 6.4861[J], HST.552[J]
Subject meets with 2.750[J], 6.4860[J]
Prereq: 2.008, 6.2040, 6.2050, 6.2060, 22.071, or permission of instructor
G (Spring)
3-3-6 units

Provides an intense project-based learning experience around the design of medical devices with foci ranging from mechanical to electro mechanical to electronics. Projects motivated by real-world clinical challenges provided by sponsors and clinicians who also help mentor teams. Covers the design process, project management, and fundamentals of mechanical and electrical circuit and sensor design. Students work in small teams to execute a substantial term project, with emphasis placed upon developing creative designs — via a deterministic design process — that are developed and optimized using analytical techniques. Includes mandatory lab. Instruction and practice in written and oral communication provided. Students taking graduate version complete additional assignments. Enrollment limited.
A. H. Slocum, E. Roche, N. C. Hanumara, G. Traverso, A. Pennes

2.750[J] Medical Device Design
Same subject as 6.4860[J]
Subject meets with 2.75[J], 6.4861[J], HST.552[J]
Prereq: 2.008, 6.2040, 6.2050, 6.2060, 22.071, or permission of instructor
U (Spring)
3-3-6 units

Provides an intense project-based learning experience around the design of medical devices with foci ranging from mechanical to electro mechanical to electronics. Projects motivated by real-world clinical challenges provided by sponsors and clinicians who also help mentor teams. Covers the design process, project management, and fundamentals of mechanical and electrical circuit and sensor design. Students work in small teams to execute a substantial term project, with emphasis placed upon developing creative designs -- via a deterministic design process -- that are developed and optimized using analytical techniques. Includes mandatory lab. Instruction and practice in written and oral communication provided. Students taking graduate version complete additional assignments. Enrollment limited.
A. H. Slocum, E. Roche, N. C. Hanumara, G. Traverso, A. Pennes

2.752 Development of Mechanical Products
Subject meets with 2.753
Prereq: 2.009, 2.750[J], or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-9 units

Focuses on evolving a product from proof-of-concept to beta prototype: Includes team building, project planning, budgeting, resource planning; models for scaling, tolerancing and reliability, patents, business planning. Students/teams start with a proof-of-concept product they bring to class or select from projects provided by instructor. In lieu of taking 12 units of 2.THU, Course 2 majors taking 2.752 may write a bachelor's thesis that documents their contributions to the product developed in the team project. Students taking the graduate version complete additional assignments. Enrollment limited; preference to Course 2 majors and minors.
A. Slocum

2.753 Development of Mechanical Products
Subject meets with 2.752
Prereq: 2.009, 2.750[J], or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Focuses on evolving a product from proof-of-concept to beta prototype: Includes team building, project planning, budgeting, resource planning; models for scaling, tolerancing and reliability, patents, business planning. Students/teams start with a proof-of-concept product they bring to class or select from projects provided by instructor. In lieu of taking 12 units of 2.THU, Course 2 majors taking 2.752 may write a bachelor's thesis that documents their contributions to the product developed in the team project. Students taking the graduate version complete additional assignments. Enrollment limited.
A. Slocum

2.76 Global Engineering
Subject meets with 2.760
Prereq: 2.008 or permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

Combines rigorous engineering theory and user-centered product design to create technologies for developing and emerging markets. Covers machine design theory to parametrically analyze technologies; bottom-up/top-down design processes; engagement of stakeholders in the design process; socioeconomic factors that affect adoption of products; and developing/emerging market dynamics and their effect on business and technology. Includes guest lectures from subject matter experts in relevant fields and case studies on successful and failed technologies. Student teams apply course material to term-long projects to create new technologies, developed in collaboration with industrial partners and other stakeholders in developing/emerging markets. Students taking graduate version complete additional assignments.
A. Winter

2.760 Global Engineering
Subject meets with 2.76
Prereq: 2.008 or permission of instructor
U (Fall)
Not offered regularly; consult department
3-0-9 units

Combines rigorous engineering theory and user-centered product design to create technologies for developing and emerging markets. Covers machine design theory to parametrically analyze technologies; bottom-up/top-down design processes; engagement of stakeholders in the design process; socioeconomic factors that affect adoption of products; and developing/emerging market dynamics and their effect on business and technology. Includes guest lectures from subject matter experts in relevant fields and case studies on successful and failed technologies. Student teams apply course material to term-long projects to create new technologies, developed in collaboration with industrial partners and other stakeholders in developing/emerging markets. Students taking graduate version complete additional assignments.
A. Winter

2.771[J] D-Lab: Supply Chains
Same subject as 15.772[J], EC.733[J]
Subject meets with 2.871
Prereq: None
U (Spring)
Not offered regularly; consult department
3-3-6 units

See description under subject 15.772[J].
S. C. Graves

2.772[J] Thermodynamics of Biomolecular Systems
Same subject as 20.110[J]
Prereq: (Biology (GIR), Calculus II (GIR), Chemistry (GIR), and Physics I (GIR)) or permission of instructor
U (Fall)
5-0-7 units. REST

See description under subject 20.110[J].
M. Birnbaum, C. Voigt

2.777 Large and Complex Systems Design and Concept Development
Subject meets with 2.778
Prereq: 2.00B, 2.007, or permission of instructor
U (Fall)
3-0-9 units

Examines structured principles and processes to develop concepts for large and complex systems. Term projects introduce students to large-scale system development with several areas of emphasis, including idea generation, concept development and refinement, system-level thinking, briefing development and presentation, and proposal generation. Interactive lectures and presentations guide students throughout the course to develop and deliver team presentations focused on solving large and complex problems. Includes a semester-long project in which students apply design tools/processes to solve a specific problem. Students taking graduate version complete the project individually.
S. Kim

2.778 Large and Complex Systems Design and Concept Development
Subject meets with 2.777
Prereq: Permission of instructor
G (Fall)
3-0-9 units

Examines structured principles and processes to develop concepts for large and complex systems. Term projects introduce students to large-scale system development with several areas of emphasis, including idea generation, concept development and refinement, system-level thinking, briefing development and presentation, and proposal generation. Interactive lectures and presentations guide students throughout the course to develop and deliver individual and team presentations focused on solving large and complex problems. Includes a semester-long project in which students apply design tools/processes to solve a specific problem. Students taking graduate version complete project individually. Limited enrollment.
S. G. Kim

Bioengineering

2.772[J] Thermodynamics of Biomolecular Systems
Same subject as 20.110[J]
Prereq: (Biology (GIR), Calculus II (GIR), Chemistry (GIR), and Physics I (GIR)) or permission of instructor
U (Fall)
5-0-7 units. REST

See description under subject 20.110[J].
M. Birnbaum, C. Voigt

2.78[J] Principles and Practice of Assistive Technology
Same subject as 6.4530[J], HST.420[J]
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
2-4-6 units

See description under subject 6.4530[J]. Enrollment may be limited.
R. C. Miller, J. E. Greenberg, J. J. Leonard

2.782[J] Design of Medical Devices and Implants
Same subject as HST.524[J]
Prereq: (Biology (GIR), Chemistry (GIR), and Physics I (GIR)) or permission of instructor
G (Spring)
3-0-9 units

Solution of clinical problems by use of implants and other medical devices. Systematic use of cell-matrix control volumes. The role of stress analysis in the design process. Anatomic fit: shape and size of implants. Selection of biomaterials. Instrumentation for surgical implantation procedures. Preclinical testing for safety and efficacy: risk/benefit ratio assessment. Evaluation of clinical performance: design of clinical trials. Project materials drawn from orthopedic devices, soft tissue implants, artificial organs, and dental implants.
I. V. Yannas, M. Spector

2.785[J] Cell-Matrix Mechanics
Same subject as HST.523[J]
Prereq: (Biology (GIR), Chemistry (GIR), and 2.001) or permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

Mechanical forces play a decisive role during development of tissues and organs, during remodeling following injury as well as in normal function. A stress field influences cell function primarily through deformation of the extracellular matrix to which cells are attached. Deformed cells express different biosynthetic activity relative to undeformed cells. The unit cell process paradigm combined with topics in connective tissue mechanics form the basis for discussions of several topics from cell biology, physiology, and medicine.
I. V. Yannas, M. Spector

2.787[J] Tissue Engineering and Organ Regeneration
Same subject as HST.535[J]
Prereq: (Biology (GIR), Chemistry (GIR), and Physics I (GIR)) or permission of instructor
G (Fall)
3-0-9 units

See description under subject HST.535[J].
M. Spector, I. V. Yannas

2.788 Mechanical Engineering and Design of Living Systems
Prereq: None
G (Fall)
4-2-6 units

For students interested in research at the interface of mechanical engineering, biology, and materials science. Specific emphasis lies on interfacing living systems with engineered materials and devices, and on engineering living system behavior.
M. Kolle, M. Guo

2.789[J] D-Lab: Design for Scale
Same subject as EC.797[J]
Subject meets with 2.729[J], EC.729[J]
Prereq: None. *Coreq: 2.008*; or permission of instructor
G (Fall)
3-2-7 units

See description under subject EC.797[J].
M. Yang, M. Kenney

2.79[J] Biomaterials: Tissue Interactions
Same subject as HST.522[J]
Prereq: (Biology (GIR), Chemistry (GIR), and Physics I (GIR)) or permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

Principles of materials science and cell biology underlying the development and implementation of biomaterials for the fabrication of medical devices/implants, including artificial organs and matrices for tissue engineering and regenerative medicine. Employs a conceptual model, the "unit cell process for analysis of the mechanisms underlying wound healing and tissue remodeling following implantation of biomaterials/devices in various organs, including matrix synthesis, degradation, and contraction. Methodology of tissue and organ regeneration. Discusses methods for biomaterials surface characterization and analysis of protein adsorption on biomaterials. Design of implants and prostheses based on control of biomaterials-tissue interactions. Comparative analysis of intact, biodegradable, and bioreplaceable implants by reference to case studies. Criteria for restoration of physiological function for tissues and organs.
I. V. Yannas, M. Spector

2.791[J] Cellular Neurophysiology and Computing
Same subject as 6.4810[J], 9.21[J], 20.370[J]
Subject meets with 2.794[J], 6.4812[J], 9.021[J], 20.470[J], HST.541[J]
Prereq: (Physics II (GIR), 18.03, and (2.005, 6.2000, 6.3000, 10.301, or 20.110[J])) or permission of instructor
U (Spring)
5-2-5 units

See description under subject 6.4810[J]. Preference to juniors and seniors.
J. Han, T. Heldt

2.792[J] Quantitative and Clinical Physiology
Same subject as 6.4820[J], HST.542[J]
Subject meets with 2.796[J], 6.4822[J], 16.426[J]
Prereq: Physics II (GIR), 18.03, or permission of instructor
U (Fall)
4-2-6 units

See description under subject 6.4820[J].
T. Heldt, R. G. Mark

2.793[J] Fields, Forces and Flows in Biological Systems
Same subject as 6.4830[J], 20.330[J]
Prereq: Biology (GIR), Physics II (GIR), and 18.03
U (Spring)
4-0-8 units

See description under subject 20.330[J].
J. Han, S. Manalis

2.794[J] Cellular Neurophysiology and Computing
Same subject as 6.4812[J], 9.021[J], 20.470[J], HST.541[J]
Subject meets with 2.791[J], 6.4810[J], 9.21[J], 20.370[J]
Prereq: (Physics II (GIR), 18.03, and (2.005, 6.2000, 6.3000, 10.301, or 20.110[J])) or permission of instructor
G (Spring)
5-2-5 units

See description under subject 6.4812[J].
J. Han, T. Heldt

2.795[J] Fields, Forces, and Flows in Biological Systems
Same subject as 6.4832[J], 10.539[J], 20.430[J]
Prereq: Permission of instructor
G (Fall)
3-0-9 units

See description under subject 20.430[J].
M. Bathe, A. J. Grodzinsky

2.796[J] Quantitative and Clinical Physiology
Same subject as 6.4822[J], 16.426[J]
Subject meets with 2.792[J], 6.4820[J], HST.542[J]
Prereq: 6.4810[J] and (2.006 or 6.2300)
G (Fall)
4-2-6 units

See description under subject 6.4822[J].
T. Heldt, R. G. Mark, L. G. Petersen

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

Develops and applies scaling laws and the methods of continuum mechanics to biomechanical phenomena over a range of length scales. Topics include structure of tissues and the molecular basis for macroscopic properties; chemical and electrical effects on mechanical behavior; cell mechanics, motility and adhesion; biomembranes; biomolecular mechanics and molecular motors. Experimental methods for probing structures at the tissue, cellular, and molecular levels. Students taking graduate version complete additional assignments.
M. Bathe, K. Ribbeck, P. T. So

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

Develops and applies scaling laws and the methods of continuum mechanics to biomechanical phenomena over a range of length scales. Topics include structure of tissues and the molecular basis for macroscopic properties; chemical and electrical effects on mechanical behavior; cell mechanics, motility and adhesion; biomembranes; biomolecular mechanics and molecular motors. Experimental methods for probing structures at the tissue, cellular, and molecular levels. Students taking graduate version complete additional assignments.
M. Bathe, K. Ribbeck, P. T. So

2.799 The Cell as a Machine
Prereq: 5.07[J], 7.05, or 18.03
G (Fall)
Not offered regularly; consult department
3-3-6 units

Examines a variety of essential cellular functions from the perspective of the cell as a machine. Includes phenomena such as nuclear organization, protein synthesis, cell and membrane mechanics, cell migration, cell cycle control, cell transformation. Lectures are provided by video twice per week; live 3-hour recitation one evening per week. Course is taken simultaneously by students at multiple universities; homework and take-home exams common to all students. Preference to students in Courses 2 and 20.
R. Kamm, M. Sheetz, H. Yu

Manufacturing

2.810 Manufacturing Processes and Systems
Prereq: 2.001, 2.006, and 2.008
G (Fall)
3-3-6 units

Introduction to manufacturing processes and manufacturing systems including assembly, machining, injection molding, casting, thermoforming, and more. Emphasis on the physics and randomness and how they influence quality, rate, cost, and flexibility. Attention to the relationship between the process and the system, and the process and part design. Project (in small groups) requires fabrication (and some design) of a product using several different processes (as listed above). Enrollment may be limited due to laboratory constraints; preference given to MechE students and students who need to satisfy degree requirements.
J. Hart, D. Wendell, W. Seering, J. Liu

2.812 Solving for Carbon Neutrality at MIT
Prereq: None
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
3-3-6 units

Working in teams, students address the problem of reducing MIT's greenhouse gas emissions in a manner consistent with the climate goals of maintaining our planet in a suitable regime to support human society and the environment. Solution scenarios include short-, middle- and long-term strategies. Experts from MIT's faculty and operations staff, as well as outside experts who address the multidisciplinary features of the problem guide solutions. These include climate science, ethics, carbon accounting, cost estimating, MIT's energy supply, energy demand, and infrastructure, new technologies, financial instruments, electricity markets, policy, human behavior, and regulation.Develops skills to address carbon neutrality at other universities, and at other scales, including cities and nations. Students taking graduate version complete additional assignments.
T. Gutowski, J. Newman

2.813 Energy, Materials, and Manufacturing
Subject meets with 2.83
Prereq: 2.008 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-0-9 units

Introduction to the major dilemma that faces manufacturing and society for the 21st century: how to support economic development while protecting the environment. Subject addresses industrial ecology, materials flows, life-cycle analysis, thermodynamic analysis and exergy accounting, manufacturing process performance, product design analysis, design for the environment, recycling and ecological economics. Combines lectures and group discussions of journal articles and selected literature, often with opposing views. Graduate students complete term-long project with report required for graduate credit.
T. G. Gutowski

2.814 Exploring Sustainability at Different Scales
Subject meets with 1.834[J], 2.834[J]
Prereq: None
U (Fall)
3-0-9 units

Develops environmental accounting tools including energy, carbon, materials, land use, and possibly others, from small scales (e.g., products and processes) to larger scales, (e.g., companies, nations and global) to reveal how reoccurring human behavior patterns have dominated environmental outcomes. Involves visiting experts and readings in areas such as ethics, economics, governance, and development to frame core issues in human relationship to the environment and future societies. Explores how local actions, including engineering interventions and behavior change, play out at larger scales associated with the concept of sustainability, and how local actions may be modified to realize sustainability. Class is participatory and includes an exploratory project. Students taking graduate version complete additional assignments. Limited to 25.
T. Gutowski

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

See description under subject 3.371[J].
D. Baskin

2.83 Energy, Materials and Manufacturing
Subject meets with 2.813
Prereq: 2.008 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Introduction to the major dilemma that faces manufacturing and society for the 21st century: how to support economic development while protecting the environment. Subject addresses industrial ecology, materials flows, life-cycle analysis, thermodynamic analysis and exergy accounting, manufacturing process performance, product design analysis, design for the environment, recycling and ecological economics. Combines lectures and group discussions of journal articles and selected literature, often with opposing views. Graduate students complete term-long project with report required for graduate credit.
T. G. Gutowski

2.830[J] Control of Manufacturing Processes
Same subject as 6.6630[J]
Prereq: 2.008, 6.2600[J], or 6.3700
G (Fall)
3-0-9 units

Statistical modeling and control in manufacturing processes. Use of experimental design and response surface modeling to understand manufacturing process physics. Defect and parametric yield modeling and optimization. Forms of process control, including statistical process control, run by run and adaptive control, and real-time feedback control. Application contexts include semiconductor manufacturing, conventional metal and polymer processing, and emerging micro-nano manufacturing processes.
D. E. Hardt, D. S. Boning

2.832 Solving for Carbon Neutrality at MIT
Prereq: None
G (Spring)
3-3-6 units

Working in teams, students address the problem of reducing MIT's greenhouse gas emissions in a manner consistent with the climate goals of maintaining our planet in a suitable regime to support human society and the environment. Solution scenarios include short-, middle- and long-term strategies. Experts from MIT's faculty and operations staff, as well as outside experts who address the multidisciplinary features of the problem guide solutions. These include climate science, ethics, carbon accounting, cost estimating, MIT's energy supply, energy demand, and infrastructure, new technologies, financial instruments, electricity markets, policy, human behavior, and regulation.Develops skills to address carbon neutrality at other universities, and at other scales, including cities and nations. Students taking graduate version complete additional assignments.
T. Gutowski, J. Newman

2.834[J] Exploring Sustainability at Different Scales
Same subject as 1.834[J]
Subject meets with 2.814
Prereq: None
G (Fall)
3-0-9 units

Develops environmental accounting tools including energy, carbon, materials, land use, and possibly others, from small scales (e.g., products and processes) to larger scales, (e.g., companies, nations and global) to reveal how reoccurring human behavior patterns have dominated environmental outcomes. Involves visiting experts and readings in areas such as ethics, economics, governance, and development to frame core issues in human relationship to the environment and future societies. Explores how local actions, including engineering interventions and behavior change, play out at larger scales associated with the concept of sustainability, and how local actions may be modified to realize sustainability. Class is participatory and includes an exploratory project. Students taking graduate version complete additional assignments. Limited to 25.
T. Gutowski

2.851[J] System Optimization and Analysis for Operations
Same subject as 15.066[J]
Prereq: Calculus II (GIR)
G (Summer)
4-0-8 units

See description under subject 15.066[J]. Restricted to Leaders for Global Operations students.
Staff

2.853 Introduction to Manufacturing Systems
Subject meets with 2.854
Prereq: 2.008
U (Fall)
3-0-9 units

Provides ways to analyze manufacturing systems in terms of material flow and storage, information flow, capacities, and times and durations of events. Fundamental topics include probability, inventory and queuing models, forecasting, optimization, process analysis, and linear and dynamic systems. Factory planning and scheduling topics include flow planning, bottleneck characterization, buffer and batch-size tactics, seasonal planning, and dynamic behavior of production systems. Graduate students are required to complete additional assignments with stronger analytical content.
S. B. Gershwin

2.854 Introduction to Manufacturing Systems
Subject meets with 2.853
Prereq: Undergraduate mathematics
G (Fall)
3-0-9 units

Provides ways to analyze manufacturing systems in terms of material flow and storage, information flow, capacities, and times and durations of events. Fundamental topics include probability, inventory and queuing models, forecasting, optimization, process analysis, and linear and dynamic systems. Factory planning and scheduling topics include flow planning, bottleneck characterization, buffer and batch-size tactics, seasonal planning, and dynamic behavior of production systems. Graduate students are required to complete additional assignments.
S. B. Gershwin

2.871 D-Lab: Supply Chains
Subject meets with 2.771[J], 15.772[J], EC.733[J]
Prereq: None
G (Spring)
Not offered regularly; consult department
3-3-6 units

Introduces concepts of supply chain design and planning with a focus on supply chains for products destined to improve quality of life in developing countries. Topics include demand estimation, process analysis and improvement, facility location and capacity planning, inventory management, and supply chain coordination. Also covers issues specific to emerging markets, such as sustainable supply chains, choice of distribution channels, and how to account for the value-adding role of a supply chain. Students conduct D-Lab-based projects on supply chain design or improvement. Students taking graduate version will complete additional assignments.
S. C. Graves

2.874[J] Process Data Analytics
Same subject as 10.354[J]
Subject meets with 2.884[J], 10.554[J]
Prereq: 18.03 or permission of instructor
Acad Year 2024-2025: U (Fall)
Acad Year 2025-2026: Not offered
4-0-8 units

See description under subject 10.354[J].
R. D. Braatz, B. Anthony

2.884[J] Process Data Analytics
Same subject as 10.554[J]
Subject meets with 2.874[J], 10.354[J]
Prereq: None
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
4-0-8 units

See description under subject 10.554[J].
R. D. Braatz, B. Anthony

2.888 Professional Seminar in Global Manufacturing Innovation and Entrepreneurship
Prereq: None
G (Spring)
2-0-1 units

Covers a broad range of topics in modern manufacturing, from models and structures for 21st-century operations, to case studies in leadership from the shop floor to the executive office. Also includes global perspectives from Asia, Europe and North America, with guest speakers from all three regions. Explores opportunities for new ventures in manufacturing. Intended primarily for Master of Engineering in Manufacturing students.
D. E. Hardt, S. B. Gershwin

2.890[J] Global Operations Leadership Seminar
Same subject as 10.792[J], 15.792[J], 16.985[J]
Prereq: None
G (Fall, Spring)
2-0-0 units
Can be repeated for credit.

See description under subject 15.792[J]. Preference to LGO students.
T. Roemer

Engineering Management

2.351[J] Introduction to Making and Hardware Ventures
Same subject as 15.351[J]
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-3 units

See description under subject 15.351[J]. Enrollment limited; application required.
C. Lowell, M. Kenney, M. Culpepper

2.900 Ethics for Engineers
Engineering School-Wide Elective Subject.
Offered under: 1.082, 2.900, 6.9320, 10.01, 16.676
Subject meets with 6.9321, 20.005
Prereq: None
U (Fall, Spring)
2-0-4 units

See description under subject 10.01.
D. A. Lauffenburger, B. L. Trout

2.907[J] Innovation Teams
Same subject as 10.807[J], 15.371[J]
Prereq: None
G (Fall)
4-4-4 units

See description under subject 10.807[J].
L. Perez-Breva, D. Hart

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

Provides an integrated approach to the development and growth of new innovative ventures. Intended for students who seek to leverage their engineering and science background through innovation-driven entrepreneurship. Emphasizes the concept that innovation-driven entrepreneurs must make a set of interdependent choices under conditions of high uncertainty, and demonstrates that venture engineering involves reducing uncertainty through a structured process of experimental learning and staged commitments. Provides deep understanding of the core technical, customer, and strategic choices and challenges facing start-up innovators, and a synthetic framework for the development and implementation of ventures in dynamic environments.
S. Stern, E. Fitzgerald

2.916[J] Money for Startups
Same subject as 10.407[J]
Prereq: None
G (Spring; second half of term)
2-0-4 units

See description under subject 10.407[J].
S. Loessberg, D. P. Hart

2.96 Management in Engineering
Engineering School-Wide Elective Subject.
Offered under: 2.96, 6.9360, 10.806, 16.653
Prereq: None
U (Fall)
3-1-8 units

Introduction and overview of engineering management. Financial principles, management of innovation, technical strategy and best management practices. Case study method of instruction emphasizes participation in class discussion. Focus is on the development of individual skills and management tools. Restricted to juniors and seniors.
H. S. Marcus, J.-H. Chun

2.961 Management in Engineering
Prereq: None
G (Fall)
3-1-8 units

Introduction and overview of engineering management. Financial principles, management of innovation, technical strategy and best management practices. Case study method of instruction emphasizes participation in class discussion. Focus is on the development of individual skills and management tools.
J.-H. Chun, H. S. Marcus

2.965[J] Global Supply Chain Management
Same subject as 1.265[J], 15.765[J], SCM.265[J]
Prereq: 15.761, 15.778, SCM.260[J], SCM.261[J], or permission of instructor
G (Spring)
Not offered regularly; consult department
2-0-4 units

See description under subject SCM.265[J].
Staff

Advanced Topics and Special Subjects

2.98 Sports Technology: Engineering & Innovation
Subject meets with 2.980
Prereq: None
G (Spring)
2-2-2 units

Examines the future of sports technology across technical disciplines, including mechanical design, biomechanics, quantified self, sports analytics, and business strategies. Includes visits by leaders in the field to discuss various industries, career pathways, and opportunities for innovation in the field. Projects explore and potentially kickoff larger research and/or entrepreneurial initiatives.
A. Hosoi, C. Chase

2.980 Sports Technology: Engineering & Innovation
Subject meets with 2.98
Prereq: None
U (Spring)
2-2-8 units

Examines the future of sports technology across technical disciplines, including mechanical design, biomechanics, quantified self, sports analytics, and business strategies. Includes visits by leaders in the field to discuss various industries, career pathways, and opportunities for innovation in the field. Projects explore and potentially kickoff larger research and/or entrepreneurial initiatives.
A. Hosoi, C. Chase

2.981 New England Coastal Ecology
Prereq: None
U (IAP)
2-0-1 units

Provides exposure to marine communities found along the coast of New England and how they fit into global patterns. Focuses on the ecology of salt marshes and rocky shores, and the biology of plants and animals that live in these complex habitats. Prepares students to recognize common inhabitants of these two communities and develops understanding of the major environmental factors affecting them, the types of ecological services they provide, and likely impacts of current and future climate change. Includes visits to field and research centers. Limited to 20.
Consult C. Bastidas

2.982 Ecology and Sustainability of Coastal Ecosystems
Prereq: None
U (Fall)
Not offered regularly; consult department
3-2-4 units

Prepares students to recognize coastal ecosystems, their major environmental and biological drivers, and common impacts that human population growth and climate change have on them. Students engage in a semester-long project to address and seek solutions to current challenges in sustainability of human activities on the coast, and to promote resilience of natural communities and ecosystem services.
J. Simpson, C. Bastidas

2.984[J] The Art and Science of Time Travel
Same subject as CMS.343[J]
Prereq: 8.02 and 18.02
G (Fall)
3-0-9 units

Explores time travel and other physical paradoxes—black holes, wormholes, and the multiverse—in the contexts of human narrative and contemporary scientific understanding. Instruction provided in the fundamental science of time travel in relativity and quantum mechanics. Students read and view classic time travel narratives in visual art and in film, and construct their own original time travel narratives. Limited to 20.
S. Lloyd, M. Reilly

2.989 Experiential Learning in Mechanical Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Provides students the opportunity to learn and gain professional experience by participating in industrial projects related to Mechanical Engineering. Minimum project length is 10 weeks. Requires a written report upon completion. Before enrolling, students must contact MechE Graduate Office for procedures and restrictions; they must also have a firm internship offer and an identified MechE faculty member who will act as supervisor. Limited to Mechanical Engineering graduate students.
N. Hadjiconstantinou

2.990 Practical Experience
Prereq: None
U (Fall, IAP, Spring, Summer)
0-1-0 units
Can be repeated for credit.

For Mechanical Engineering undergraduates participating in curriculum-related off-campus experiences in mechanical engineering. Before enrolling, students must have an employment offer from a company or organization and must find a Mech E advisor. Upon completion of the coursework the student must submit a detailed design notebook, approved by the MIT advisor. Subject to departmental approval. Consult Department Undergraduate Office for details on procedures and restrictions.
Consult R. Karnik

2.991 Introduction to Graduate Study in Mechanical Engineering
Prereq: None
G (Fall)
1-2-0 units

Familiarizes students with the requirements for their desired degree and the resources, both at MIT and beyond, to help them reach their educational and professional goals. Series of interactive lectures and seminars guides students through various aspects of life critical to navigating graduate school successfully. Topics include course requirements, PhD qualifying examinations, advisor/advisee relationships, funding and fellowships, mental health and wellbeing, housing options in the Boston area, and career options after graduation. Limited to first-year graduate students.
C. Buie

2.992 Professional Industry Immersion Project
Prereq: Permission of instructor
G (Summer)
Units arranged

Provides students a unique opportunity to participate in industry-based projects. Students gain professional industry experience in mechanical engineering projects that complement their academic experiences. Each project has a company advisor, a specific advisor, and a course instructor. Course staff help students connect with specific companies and collaboratively design a project of mutual interest and benefit. Requires a written report and project presentation upon completion of a minimum of 10 weeks of off-campus activities. Limited to Mechanical Engineering graduate students.
B. Anthony

2.993 Independent Study
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Designed for undergraduates wanting to continue substantial projects of own choice, under faculty supervision, in mechanical engineering. Work may be of experimental, theoretical, or design nature. Projects may be arranged individually in most fields of department interest, i.e., in mechanics, design and manufacturing, controls and robotics, thermal science and energy engineering, bioengineering, ocean engineering and nanotechnology. 2.993 is letter-graded; 2.994 is P/D/F.
Consult R. Karnik

2.994 Independent Study
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Designed for undergraduates wanting to continue substantial projects of own choice, under faculty supervision, in mechanical engineering. Work may be of experimental, theoretical, or design nature. Projects may be arranged individually in most fields of department interest, i.e., in mechanics, design and manufacturing, controls and robotics, thermal science and energy engineering, bioengineering, ocean engineering and nanotechnology. 2.993 is letter-graded; 2.994 is P/D/F.
Consult R. Karnik

2.995 Advanced Topics in Mechanical Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Assigned reading and problems or research in distinct areas, either theoretical or experimental, or design. Arranged on individual basis with instructor in the following areas: mechanics and materials, thermal and fluid sciences, systems and design, biomedical engineering, and ocean engineering. Can be repeated for credit only for completely different subject matter.
Consult R. Abeyaratne

2.996 Advanced Topics in Mechanical Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Assigned reading and problems or research in distinct areas, either theoretical or experimental, or design. Arranged on individual basis with instructor in the following areas: mechanics and materials, thermal and fluid sciences, systems and design, biomedical engineering, and ocean engineering. Can be repeated for credit only for completely different subject matter.
Consult R. Abeyaratne

2.997 Advanced Topics in Mechanical Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Assigned reading and problems or research in distinct areas, either theoretical or experimental, or design. Arranged on individual basis with instructor in the following areas: mechanics and materials, thermal and fluid sciences, systems and design, biomedical engineering, and ocean engineering. Can be repeated for credit only for completely different subject matter.
Consult R. Abeyaratne

2.998 Advanced Topics in Mechanical Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Assigned reading and problems or research in distinct areas, either theoretical or experimental, or design. Arranged on individual basis with instructor in the following areas: mechanics and materials, thermal and fluid sciences, systems and design, biomedical engineering, and ocean engineering. Can be repeated for credit only for completely different subject matter.
Consult R. Abeyaratne

2.S007 Special Subject in Mechanical Engineering
Prereq: None
U (Spring)
Units arranged

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

2.S009 Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
Units arranged

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

2.S19 Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
Units arranged

Lecture, seminar or laboratory course consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
B. Aulet, A. Hosoi, M. Jester, S. Johnson, C. Lawson

2.S372 Special Subject in Mechanical Engineering
Prereq: None
G (Spring)
Units arranged

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

2.S670 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

2.S679 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

2.S790-2.S792 Graduate Special Subject in Bioengineering
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Advanced lecture, seminar or laboratory course consisting of material in the broadly-defined field of bioengineering not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
Consult R. Kamm

2.S793 Graduate Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
3-3-6 units

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

2.S794 Graduate Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Units arranged [P/D/F]

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

2.S795 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Fall)
Units arranged
Can be repeated for credit.

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

2.S796 Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

2.S797 Graduate Special Subject in Mechanical Engineering
Prereq: None
G (Spring)
Not offered regularly; consult department
Units arranged

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

2.S885 Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
3-3-6 units

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

2.S97 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

Lecture, seminar or laboratory course consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S972-2.S974 are graded P/D/F.
Consult R. Karnik

2.S971 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
3-3-6 units
Can be repeated for credit.

Lecture, seminar or laboratory course consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S972-2.S974 are graded P/D/F.
Consult R. Karnik

2.S972 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Fall, Spring)
Not offered regularly; consult department
3-1-2 units
Can be repeated for credit.

Lecture, seminar or laboratory course consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S972-2.S974 are graded P/D/F.
Consult K. Zolot

2.S973 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Units arranged [P/D/F]
Can be repeated for credit.

Lecture, seminar or laboratory course consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S972-2.S974 are graded P/D/F.
Consult R. Karnik

2.S974 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

2.S975 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (IAP)
Units arranged [P/D/F]
Can be repeated for credit.

Lecture, seminar or laboratory course consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. See staff for scheduling information. Limited to 16.
Consult T. Consi

2.S976 Special Subject in Mechanical Engineering
Prereq: None
U (Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

2.S977 Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
4-0-8 units
Can be repeated for credit.

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

2.S978 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

2.S979 Graduate Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
4-0-8 units
Can be repeated for credit.

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

2.S980 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Advanced lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
R. Abeyaratne

2.S981 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Spring)
Units arranged
Can be repeated for credit.

Advanced lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
Consult R. Abeyaratne

2.S982 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Advanced lecture, seminar or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
Consult V. Sudhir

2.S983 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (IAP)
Units arranged
Can be repeated for credit.

Advanced lecture, seminar or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
A. Hosoi, C. Chase

2.S984 Graduate Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
3-0-9 units

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

2.S985 Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
3-3-6 units

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

2.S986 Special Subject in Mechanical Engineering
Prereq: None
G (Spring)
Not offered regularly; consult department
Units arranged

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

2.S987 Special Subject in Mechanical Engineering
Prereq: None
G (Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

2.S988 Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Units arranged
Can be repeated for credit.

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

2.S989 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

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

2.S990 Graduate Special Subject in Mechanical Engineering
Prereq: None
G (Spring)
Units arranged
Can be repeated for credit.

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

2.S991 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Spring)
Not offered regularly; consult department
Units arranged

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

2.S992 Graduate Special Subject in Mechanical Engineering
Prereq: None
G (Spring)
Units arranged
Can be repeated for credit.

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

2.S993 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
Units arranged
Can be repeated for credit.

Lecture, seminar or laboratory course consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S972-2.S974, 2.S992 are graded P/D/F.
R. Karnik

2.S994 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Spring)
Units arranged
Can be repeated for credit.

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S972-2.S974 and 2.S992 are graded P/D/F.
Consult R. Karnik

2.S995 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
0-6-0 units
Can be repeated for credit.

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S972-2.S974 and 2.S992 are graded P/D/F.
Consult I. Hunter

2.S996 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Advanced lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
Consult R. Abeyaratne

2.S997 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

Advanced lecture, seminar or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
Consult F. Ahmed

2.S998 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Advanced lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
Consult R. Abeyaratne, J. Hart

2.S999 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Spring)
Units arranged
Can be repeated for credit.

Advanced lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
Consult R. Abeyaratne, T. Gutowski

Thesis, Research and Practice

2.978 Instruction in Teaching Engineering
Subject meets with 1.95[J], 5.95[J], 7.59[J], 8.395[J], 18.094[J]
Prereq: Permission of instructor
G (Fall)
Units arranged [P/D/F]

Participatory seminar focuses on the knowledge and skills necessary for teaching engineering in higher education. Topics include research on learning; course development; promoting active learning, problemsolving, and critical thinking in students; communicating with a diverse student body; using educational technology to further learning; lecturing; creating effective tests and assignments; and assessment and evaluation. Field-work teaching various subjects in the Mechanical Engineering department will complement classroom discussions.
J. Rankin

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

For students participating in departmentally approved undergraduate teaching programs. Students assist faculty in the design and execution of the curriculum and actively participate in the instruction and monitoring of the class participants. Students prepare subject materials, lead discussion groups, and review progress. Credit is arranged on a subject-by-subject basis and is reviewed by the department.
A. E. Hosoi

2.999 Engineer's Degree Thesis Proposal Preparation
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.

For students who must do additional work to convert an SM thesis to a Mechanical Engineer's (ME) or Naval Engineer's (NE) thesis, or for students who write an ME/NE thesis after having received an SM degree.
R. Abeyaratne, M. S. Triantafyllou

2.C01 Physical Systems Modeling and Design Using Machine Learning
Subject meets with 2.C51
Prereq: 2.086 and 6.C01
U (Spring; second half of term)
1-3-2 units

Building on core material in 6.C01, encourages open-ended exploration of the increasingly topical intersection between artificial intelligence and the physical sciences. Uses energy and information, and their respective optimality conditions, to define supervised and unsupervised learning algorithms as well as ordinary and partial differential equations. Subsequently, physical systems with complex constitutive relationships are drawn from elasticity, biophysics, fluid mechanics, hydrodynamics, acoustics, and electromagnetics to illustrate how machine learning-inspired optimization can approximate solutions to forward and inverse problems in these domains. Students taking graduate version complete additional assignments. Students cannot receive credit without completion of the core subject 6.C01.
G. Barbastathis

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

Explores the contemporary computational understanding of imaging: encoding information about a physical object onto a form of radiation, transferring the radiation through an imaging system, converting it to a digital signal, and computationally decoding and presenting the information to the user. Introduces a unified formulation of computational imaging systems as a three-round "learning spiral": the first two rounds describe the physical and algorithmic parts in two exemplary imaging systems. The third round involves a class project on an imaging system chosen by students. Undergraduate and graduate versions share lectures but have different recitations. Involves optional "clinics" to even out background knowledge of linear algebra, optimization, and computational imaging-related programming best practices for students of diverse disciplinary backgrounds. Students taking graduate version complete additional assignments.
G. Barbastathis, J. LeBeau, R. Ram, S. You

2.C51 Physical Systems Modeling and Design Using Machine Learning
Subject meets with 2.C01
Prereq: 6.C51 and (18.0751 or 18.0851)
G (Spring; second half of term)
1-3-2 units

Building on core material in 6.C51, encourages open-ended exploration of the increasingly topical intersection between artificial intelligence and the physical sciences. Uses energy and information, and their respective optimality conditions, to define supervised and unsupervised learning algorithms as well as ordinary and partial differential equations. Subsequently, physical systems with complex constitutive relationships are drawn from elasticity, biophysics, fluid mechanics, hydrodynamics, acoustics, and electromagnetics to illustrate how machine learning-inspired optimization can approximate solutions to forward and inverse problems in these domains. Students taking graduate version complete additional assignments. Students cannot receive credit without completion of the core subject 6.C51.
G. Barbastathis

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

Contemporary understanding of imaging is computational: encoding onto a form of radiation the information about a physical object, transferring the radiation through the imaging system, converting it to a digital signal, and computationally decoding and presenting the information to the user. This class introduces a unified formulation of computational imaging systems as a three-round "learning spiral": the first two rounds, instructors describe the physical and algorithmic parts in two exemplary imaging systems. The third round, students conduct themselves as the class project on an imaging system of their choice. The undergraduate and graduate versions share lectures but have different recitations. Throughout the term, we also conduct optional "clinics" to even out background knowledge of linear algebra, optimization, and computational imaging-related programming best practices for students of diverse disciplinary backgrounds.
G. Barbastathis, J. LeBeau, R. Ram, S. You

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

Provides students with skills to prepare for and excel in the world of industry. Emphasizes practical application of career theory and professional development concepts. Introduces students to relevant and timely resources for career development, provides students with tools to embark on a successful internship search, and offers networking opportunities with employers and MIT alumni. Students work in groups, led by industry mentors, to improve their resumes and cover letters, interviewing skills, networking abilities, project management, and ability to give and receive feedback. Objective is for students to be able to adapt and contribute effectively to their future employment organizations. A total of two units of credit is awarded for completion of the fall and subsequent spring term offerings. Application required; consult UPOP website for more information.
K. Tan-Tiongco, D. Fordell

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

Provides sophomores across all majors with opportunities to develop and practice communication, teamwork, and problem-solving skills to become successful professionals in the workplace, particularly in preparation for their summer industry internship. This immersive, multi-day Team Training Workshop (TTW) is comprised of experiential learning modules focused on expanding skills in areas that employers report being most valuable in the workplace. Modules are led by MIT faculty with the help of MIT alumni and other senior industry professionals. Skills applied through creative simulations, team problem-solving challenges, oral presentations, and networking sessions with prospective employers. Enrollment limited to those in the UPOP program.
K. Tan-Tiongco, D. Fordell

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

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

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

Individual self-motivated study, research, or design project under faculty supervision. Departmental program requirement: minimum of 6 units. Instruction and practice in written communication provided.
Consult R. Karnik

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

Individual study, research, or laboratory investigations under faculty supervision, including individual participation in an ongoing research project. See projects listing in Undergraduate Office, 1-110, for guidance.
Consult D. Rowell

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

Individual study, research, or laboratory investigations under faculty supervision, including individual participation in an ongoing research project. See projects listing in Undergraduate Office, 1-110, for guidance.
Consult N. Fang, K. Kamrin