DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

The Department of Civil and Environmental Engineering (CEE) seeks to understand the world, invent, and innovate with creative design. To address some of the greatest challenges of our time, the department uses approaches that range from basic scientific principles to complex engineering design, at scales from the nano to the global. Emphasizing the use of quantitative approaches, CEE features two vibrant centers of gravity: environment (what exists as natural systems) and infrastructure (what is created by human activity). The department is organized into two laboratories around these focus areas: the Parsons Laboratory for Environmental Science and Engineering and the Pierce Laboratory for Infrastructure Science and Engineering, which emphasizes materials and systems. CEE consists of people from a broad range of academic disciplines who work together to contribute to exciting intellectual networks across the department and MIT, solving tomorrow’s problems to build a better future through discovery and innovation.

An education in civil and environmental engineering provides an excellent foundation to solve the world’s greatest challenges in areas such as sustainability, environment, or energy. It prepares students for careers in fields as diverse as engineering design, education, law, medicine, and public health, as well as for graduate study in engineering and science. Graduates teach and carry out research in universities, work for large firms, start their own businesses, and hold leadership positions in government and nonprofit organizations. The department’s undergraduate program provides a solid background in science and engineering fundamentals while emphasizing hands-on design and research projects that provide real-world context. Students focus on the use of large data, computation, probability, and data analysis, and learn how to combine theory, experiments, and modeling to understand and solve complex science and engineering problems.

Course 1-ENG is the undergraduate degree program offered by The Department of Civil and Environmental Engineering. 1-ENG leads to a Bachelor of Science in Engineering as Recommended by the Department of Civil and Environmental Engineering, and has a flexible curriculum that supplements a civil and environmental engineering foundation with an area of core coursework in a field of specialization, introducing exciting opportunities for disciplinary or multidisciplinary focus. The department is seeking general engineering accreditation from ABET for this degree.

The department also offers graduate degrees within the broadly defined areas of environmental science and engineering (which includes environmental chemistry, environmental fluid mechanics, environmental microbiology, and hydrology and hydroclimatology), mechanics of materials and structures, geotechnical engineering and geomechanics, and transportation. The depth and breadth of coursework and research required differ for each degree program.

The department’s graduate degrees are as follows: Master of Engineering (MEng), Master of Science in Transportation (MST), Master of Science (SM), Civil Engineer, Environmental Engineer, Doctor of Philosophy (PhD), and Doctor of Science (ScD).

Undergraduate Study

The Department of Civil and Environmental Engineering offers an undergraduate program, Course 1-ENG, leading to the Bachelor of Science in Engineering as Recommended by the Department of Civil and Environmental Engineering.

Undergraduates are encouraged to participate in the research activities of the department and in many cases obtain degree credit for such work. In general, students are encouraged to plan their programs for the third and fourth years so they dovetail with possible graduate study, including the department’s Master of Engineering degree. This is readily accomplished by those students who embark on the departmental program in their second year. Under certain circumstances, students are permitted to work toward receiving simultaneous undergraduate and graduate degrees.

Bachelor of Science in Engineering as Recommended by the Department of Civil and Environmental Engineering (Course 1-ENG)

The degree is designed to prepare students to make an impact in solving the world’s greatest challenges. The program, for which the department plans to obtain ABET accreditation in general engineering, offers possibilities to select tracks of study for in-depth exploration of particular areas, or to focus on cross-cutting, multidisciplinary studies within and outside the department in emerging areas of civil and environmental engineering, broadly defined. Refer to the website (http://cee.mit.edu/undergraduate) for further details on sample educational tracks and educational opportunities.

The undergraduate program provides significant flexibility through a track structure that is consistent with the diverse nature of our disciplinary groups and responsive to students’ interests in new educational offerings. The program is built around a solid foundation in mathematics, big data, sensing, and computing, and is complemented by laboratory subjects on data analysis. It includes a capstone subject that provides ample opportunities for students to solve complex problems. The program enables students to design individualized programs to meet particular educational objectives. For example, students interested in careers in fields such as sustainability, environmental science and engineering, microbiology, sustainable materials, geochemistry, energy resources, structural/architectural engineering, oceanography, or environmental law can design programs that provide both depth and breadth.

The main component of the program is a small set of General Department Requirements (GDRs) consisting of subjects that focus
on mathematics, computation, probability and statistics, and data analysis, plus a capstone. Students select one of three core options, each consisting of subjects that build a solid background in one of three areas: environment, mechanics and materials, or systems. Their selections of a core and a consistent set of four or five restricted elective subjects, in consultation with a CEE faculty advisor, define their track of undergraduate study. Restricted electives may be selected from subjects within or outside the Department of Civil and Environmental Engineering.

To satisfy the CI-M component of the Communication Requirement, students must take two of the department’s CI-M subjects (1.013 Senior Civil and Environmental Engineering Design and either 1.011 Project Evaluation and Management or 1.092 Traveling Research Environmental eXperience (TREX): Fieldwork Analysis and Communication) or, if appropriate, take one Course 1 CI-M subject and petition the Subcommittee on the Communication Requirement to substitute one CI-M from another science or engineering field. Any outside CI-M must fit into the coherent program of electives approved by the student’s academic advisor and must be approved by the undergraduate officer. The remaining part of the program consists of unrestricted electives, bringing the total number of required units beyond the General Institute Requirements to 180.

**Minor in Civil and Environmental Systems**
The Minor in Civil and Environmental Systems consists of the following subjects:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.011</td>
<td>Project Evaluation and Management</td>
<td>12</td>
</tr>
<tr>
<td>1.020</td>
<td>Principles of Energy and Water Sustainability</td>
<td>12</td>
</tr>
<tr>
<td>1.042</td>
<td>Urban Networks</td>
<td>6</td>
</tr>
<tr>
<td>1.041</td>
<td>Transportation Systems Modeling</td>
<td>12</td>
</tr>
<tr>
<td>1.075</td>
<td>Water Resource Systems</td>
<td>12</td>
</tr>
<tr>
<td>1.101</td>
<td>Introduction to Civil and Environmental Engineering Design I</td>
<td>6</td>
</tr>
<tr>
<td>1.102</td>
<td>Introduction to Civil and Environmental Engineering Design II</td>
<td>6</td>
</tr>
</tbody>
</table>

Total Units 66

**Minor in Civil Engineering**
The Minor in Civil Engineering consists of the following subjects:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.035</td>
<td>Multiscale Characterization of Materials</td>
<td>12</td>
</tr>
<tr>
<td>1.036</td>
<td>Structural Mechanics and Design</td>
<td>12</td>
</tr>
<tr>
<td>1.050</td>
<td>Solid Mechanics</td>
<td>12</td>
</tr>
<tr>
<td>1.060A</td>
<td>Fluid Mechanics I</td>
<td>6</td>
</tr>
<tr>
<td>1.060B</td>
<td>Fluid Mechanics II</td>
<td>6</td>
</tr>
<tr>
<td>1.101</td>
<td>Introduction to Civil and Environmental Engineering Design I</td>
<td>6</td>
</tr>
</tbody>
</table>

1.102 Introduction to Civil and Environmental Engineering Design II 6

Total Units 60

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

<table>
<thead>
<tr>
<th>Subject</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.018A(J)</td>
<td>Fundamentals of Ecology I</td>
<td>6</td>
</tr>
<tr>
<td>1.060A</td>
<td>Fluid Mechanics I</td>
<td>6</td>
</tr>
<tr>
<td>1.061A</td>
<td>Transport Processes in the Environment I</td>
<td>6</td>
</tr>
<tr>
<td>1.070A(J)</td>
<td>Introduction to Hydrology and Water Resources</td>
<td>6</td>
</tr>
<tr>
<td>1.080A</td>
<td>Environmental Chemistry I</td>
<td>6</td>
</tr>
<tr>
<td>1.089A</td>
<td>Environmental Microbiology I</td>
<td>6</td>
</tr>
<tr>
<td>1.091</td>
<td>Traveling Research Environmental eXperience (TREX): Fieldwork Analysis and Communication</td>
<td>3</td>
</tr>
<tr>
<td>1.092</td>
<td>Traveling Research Environmental eXperience (TREX): Fieldwork Analysis and Communication</td>
<td>9</td>
</tr>
<tr>
<td>1.106</td>
<td>Environmental Fluid Transport Processes and Hydrology Laboratory</td>
<td>6</td>
</tr>
<tr>
<td>1.107</td>
<td>Environmental Chemistry and Biology Laboratory</td>
<td>6</td>
</tr>
</tbody>
</table>

Total Units 60

Substitution of equivalent subjects offered by other departments is allowed, with permission of the minor advisor. However, at least three full 12-unit subjects must be Course 1 subjects.

For a general description of the minor program, see Undergraduate Education (http://catalog.mit.edu/mit/undergraduate-education/academic-programs/minors).

**Other Undergraduate Opportunities**

**Undergraduate Practice Opportunities Program**
The Undergraduate Practice Opportunities Program (UPOP) is a full-year co-curricular professional development program sponsored by the School of Engineering that prepares sophomores for success in the workplace. UPOP is open to all sophomores, regardless of major. Over the course of the program, students receive classroom instruction and personalized coaching focused on advancing both short- and long-term professional goals, with support provided in finding and securing a summer internship. UPOP students participate in professional development workshops and one-to-one coaching during both fall and spring semesters. Students also attend a one-week course over IAP focusing on foundational decision making, team dynamics and development, and communication—essential tools for workplace success. Experiential modules are taught by MIT faculty and coached by MIT alumni mentor-instructors,
providing students with an opportunity to practice professional skills with highly experienced industry professionals. UROP’s two-unit curriculum also serves as the foundation of the Bernard M. Gordon-MIT Engineering Leadership (GEL) Program. Contact the Undergraduate Practice Opportunities Program (upop@mit.edu), Room 12-193, 617-253-0077, or Leo McGonagle, executive director, for further information.

Research Opportunities
Students wishing to work closely with a member of the faculty on research may obtain permission to register for thesis, or to enroll in 1.999 Undergraduate Studies in Civil and Environmental Engineering. In addition, numerous possibilities exist in the Undergraduate Research Opportunities Program (UROP) (http://catalog.mit.edu/mit/undergraduate-education/academic-research-options/undergraduate-research-opportunities-program), and several UROP traineeships are awarded to undergraduates by the department each spring.

Graduate Study
The Department of Civil and Environmental Engineering (CEE) grants the following advanced degrees: Master of Engineering in Civil and Environmental Engineering, Master of Science in Transportation, Master of Science, Master of Science, Civil Engineer, Doctor of Science, and Doctor of Philosophy. The Institute’s general requirements for these degrees are described under Graduate Education (http://catalog.mit.edu/mit/graduate-education). Detailed information on the departmental requirements for each degree may be obtained from the Academic Programs Office, Room 1-290.

Admission Requirements
The primary requirements for graduate study are a strong intellect and the ability and interest to pursue rigorous, focused study. Applicants do not need an undergraduate degree in civil or environmental engineering. For students with backgrounds in other branches of engineering, science, and certain social sciences, opportunities exist for interdisciplinary research that brings people of complementary backgrounds together in search of solutions to major societal problems. For example, graduate students and faculty in the department have experience in geology, chemistry, physics, biology, computer science, economics, political science, sociology, architecture, urban and regional planning, and management.

All applicants are required to submit scores from the GRE General Test. Applicants whose first language is not English are required to submit scores from either the International English Language Testing System (IELTS), the preferred exam, or the Test of English as a Foreign Language (TOEFL). More information about individual graduate programs can be obtained from the website (http://cee.mit.edu) or by email (cee-admissions@mit.edu).

Master of Engineering
The Department of Civil and Environmental Engineering's Master of Engineering (MEng) (http://cee.mit.edu/master-of-engineering) is a nine-month program that provides a practice-oriented education with a focus on real-world engineering challenges. It is designed for people with a bachelor's degree in engineering (or related field) who want to enter or return to professional practice. Our graduates routinely join leading engineering design firms, consulting companies, and government agencies; some go on to pursue a PhD. The distinctive element of the program is a professional practice experience comprising a group project and an individual, practice-oriented thesis.

MEng students specialize in one of four tracks: environmental and water quality engineering, geotechnology, high-performance structures, or transportation.

Because of their intensive coursework, MEng students do not have time to work as research or teaching assistants. Admission standards are the same as for the Master of Science degree. Strong communication skills are expected. MIT undergraduates may apply to the program at the end of their third year.

Master of Science and Doctoral Degrees
Programs of graduate study are available in the following areas: environmental chemistry, environmental fluid mechanics, environmental microbiology, hydrology and hydroclimatology, the mechanics of materials and structures, and transportation.

The program in environmental chemistry focuses on processes governing the fates and effects of natural and anthropogenic chemicals. In environmental systems, quantitative knowledge is commonly sought using chemical measurements made in controlled laboratory experiments, as well as in environmental samples of air, water, sediments, soils, and biota. Such data are synthesized within models so as to predict how the combination of chemical transport and transformation processes control human and ecosystem exposures. Knowledge of the mechanisms that regulate the cycling of materials through natural and man-made ecosystems is essential to address and avoid environmental problems.

Environmental fluid mechanics considers the physical processes associated with water and water motion that are essential to the understanding, protection, and improvement of the environment. The program includes theoretical, numerical, experimental, and field studies, which range in scale from the swimming of microorganisms to the transport of carbon dioxide through the global ocean basin. While rooted in the fundamental analyses of fluid physics, our projects are guided by practical problems in environmental science such as the protection of coastal water quality, the prediction and mitigation of coastal erosion, and the restoration of channels and coastal zones.
Environmental microbiology focuses on microbial properties and processes that define the structure and function of natural and man-made ecosystems. Water is a key medium through which energy and elements are transported within and between ecosystems, and it is also a conduit for the transport of anthropogenic materials and waste. Microorganisms are the primary living constituents in aquatic ecosystems and mediate globally important processes. Our studies are grounded in microbial genomics, population genetics, physiology, ecology, evolution and environmental science and engineering. This program predominantly admits students interested in pursuing PhD-level research.

Graduate study in hydrology and hydroclimatology considers a range of scientific and engineering issues associated with water, energy and biogeochemical cycles. These include better understanding of basic processes and fluxes, such as precipitation and evapotranspiration, partitioning of moisture at the land surface, chemical transport processes in the surface and subsurface, and coupled multiphase flow and geomechanics. It also includes the investigation of critical water problems, such as the effects of climate change on the global distribution of fresh water, extreme events and hazards, the connections between water and human health, and the water-food-energy nexus. The hydrology program is multi-faceted, and it combines theoretical, modeling, laboratory, and field studies. It is also multi-disciplinary, embracing many fields, including fluid mechanics, chemistry, biology, physical geography, mathematics, computer science, remote sensing, geology, and geophysics. This program predominantly admits students interested in pursuing PhD-level research.

The graduate program in the mechanics of materials and structures emphasizes fundamental understanding of, and innovative approaches to, materials and structural engineering problems by considering a vast range of scales from the nano to the macro, and by introducing new methods such as nanotechnology, innovative laboratory approaches to experimental mechanics, and innovations in design. The impact of these studies includes the development and use of better infrastructure materials, new structural design, advanced manufacturing methods such as additive manufacturing and self-assembly, bio-inspired materials, and designing for increased performance by improving safety, lowering costs, and mitigating the impact on the environment. The program emphasizes studies of the mechanical behavior of materials and the mechanics of materials at all scales using methods of statistical mechanics and multiscaling. Under this broad domain of study also falls geotechnical engineering and geomechanics that address a wide range of problems posed by the spatial variability and complex material properties of soils and rocks. Geotechnical engineers deal with the design and construction of major infrastructure projects ranging from tunnels to offshore structures, and with natural hazards from landslides to earthquakes. Geoenvironmental problems of subsurface waste containment, groundwater contamination and site remediation are also a major focus of the profession, as are problems related to resource extraction, including engineered geothermal systems. The graduate program includes core subjects in soil mechanics; engineering geology and groundwater hydrology; application subjects involving geotechnical and geoenvironmental problems; and specialized subjects in geomaterial (soil and rock) behavior, theoretical and experimental methods, and underground construction.

Graduate study in transportation examines all major forms of transportation, including passenger and freight systems, as well as the increasing demand for transportation systems at the local, regional, and international levels. Projects and coursework consider the critical issues involved in meeting transportation needs in a sustainable way, considering all modes of transportation where appropriate. The interdisciplinary Transportation program, based in CEE, emphasizes the complexity of transportation and its dependence on the interaction of technology, operations, planning, management, and policy making. Our focus includes study of the interactions of transportation infrastructure and operations, urban spatial structure and land use, economic growth, resource and energy use, and environmental impacts at various spatial and temporal scales.

Financial Assistance
The research of the department is an integral part of the graduate program. All doctoral students receive appointments as research or teaching assistants, as do the majority of our SM and MST students. Most of these appointments fully cover tuition, individual health insurance, and reasonable living expenses in the Boston area.

Applicants are encouraged to apply for traineeships and fellowships offered nationally by the National Science Foundation, NASA, DOE, and other governmental agencies that traditionally support students in the department. For an extensive list of such opportunities, visit the Office of the Dean for Graduate Education website (http://odge.mit.edu/finances/fellowships).

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

Computational Science and Engineering
The Computational Science and Engineering (CSE) (http://computationalengineering.mit.edu/education) program allows students to specialize at the doctoral level in a computation-related field of their choice through focused coursework and a doctoral thesis through a number of participating host departments. The CSE program is administered jointly by the Center for Computational Engineering (CCE) and the host departments, with the emphasis of thesis research activities being the development of new computational methods and/or the innovative application of computational techniques to important problems in engineering and science. For more information, see the full program description.
Graduate Programs in Transportation
MIT provides a broad range of opportunities for transportation-related education. Courses and classes span the School of Engineering, the Sloan School of Management, and the School of Architecture and Planning, with many activities covering interdisciplinary topics that prepare students for future industry, government, or academic careers.

A variety of graduate degrees are available to students interested in transportation studies and research, including a Master of Science in Transportation and PhD in Transportation, described under Interdisciplinary Graduate Programs.

Leaders for Global Operations
The 24-month Leaders for Global Operations (LGO) (http://lgo.mit.edu) 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 six engineering programs, some of which have optional or required LGO tracks. After graduation, alumni take on leadership roles at top global manufacturing and operations companies.

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 supervised 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 under Interdisciplinary Graduate Programs (http://catalog.mit.edu/interdisciplinary/graduate-programs/joint-program-woods-hole-oceanographic-institution).

Inquiries
Detailed information about the academic policies and programs of the department (http://cee.mit.edu) may be obtained by writing (cee-ano@mit.edu) or visiting the Academic Programs Office, Room 1-290, 617-253-9723.

Research Laboratories and Activities
The Department of Civil and Environmental Engineering occupies two buildings on the MIT campus: Building 1 (the Henry L. Pierce Laboratory) and Building 48 (the Ralph M. Parsons Laboratory for Environmental Science and Engineering). These buildings contain specialized research and teaching facilities. In addition, department faculty collaborate with many of the interdisciplinary centers, labs and programs, notably the Concrete Sustainability Hub, Singapore-MIT Alliance for Research and Technology, and Center for Global Change Science, described under Research and Study.

Ralph M. Parsons Laboratory for Environmental Science and Engineering
The Ralph M. Parsons Laboratory for Environmental Science and Engineering is a four-story structure containing about 31,000 square feet of classrooms, teaching and research laboratories, machine shops, computer facilities, and offices. Approximately 18 faculty members, 75 graduate students, and 33 postdocs and 11 research staff have offices and laboratories on the premises. Facilities exist for hydrodynamic studies involving flow through vegetation, free surface flows, and flows in porous media. Seven laboratories are set up for research in inorganic chemistry, and organic geoatmospheric chemistry, and microbial ecology/genomics/biochemistry. Especially notable instrumentation includes several gas chromatographs, mass spectrometers, a GC-MS atomic absorption spectrophotometers, and an ICP-MS, alpha and gamma spectrometry counting systems, scintillation counters, several flow cytometers, DNA sequencing equipment and walk in incubators and cold room, as well as several -80°C freezers.

One laboratory is a dedicated teaching facility for fluid mechanics, hydrology, aquatic and atmospheric chemistry, and microbiology. Equipment is available for instruction in a wide range of field sampling methods, biological and microbiological evaluations, and instrumental chemical analyses of natural waters. In addition to a recent acquisition of a two-channel auto analyzer, two state-of-the-art analytical instruments have been purchased for the student laboratory: an inductively coupled plasma-mass spectrometer and a gas chromatographic-mass spectrometer.

Henry L. Pierce Laboratory
Located in one of MIT’s original buildings, overlooking the Charles River, the Pierce Laboratory, includes over 40,000 square feet of classrooms, teaching and research laboratories, and offices for approximately 140 graduate students, 32 faculty members and research staff, and 25 postdocs.

Research activities focus on two major areas: materials/mechanics and systems/transportation. Among the classrooms is the state-of-the-art Bechtel Lecture Hall. The facilities include an undergraduate teaching/project laboratory, a materials testing laboratory, and geotechnical laboratories. The materials laboratory has a machine shop, electronics room, and support equipment (3-D printer, and laser cutter, and others), used to process, fabricate, and create prototype devices and specimens, to test materials under various stress and environmental conditions, and to investigate physical properties of materials and structures. The laboratory includes
several automated universal test frames, a biaxial loading system, and an environmentally controlled nano-indentation system. The geotechnical laboratories combine conventional and state-of-the-art as well as a number of specialty research devices. Capabilities and equipment include industrial radiography; centralized data acquisition; computer-automated consolidation triaxial cells; simple shear devices; and a hollow cylinder apparatus.

The Pierce Laboratory offers diverse and advanced computational facilities. The computing facilities feature various structural, project management, geotechnical, and materials modeling software such as SAP, GSA, PLAXIS, AutoCAD, KeyCreator, ANSYS, ABAQUS, as well as various molecular and quantum mechanical modeling software and others.

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Professor Emeritus of Mechanical Engineering

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

Amedeo R. Odoni, PhD
T. Wilson (1953) Professor Emeritus
Professor Emeritus of Aeronautics and Astronautics
Professor Emeritus of Civil and Environmental Engineering

Daniel Roos, PhD
Professor Emeritus of Data, Systems, and Society
Professor Emeritus of Civil and Environmental Engineering

Daniele Veneziano, PhD
Professor Emeritus of Civil and Environmental Engineering

Nigel H. M. Wilson, PhD
Professor Emeritus of Civil and Environmental Engineering

Fundamentals

1.00 Engineering Computation and Data Science
Subject meets with 1.001
Prereq: Calculus I (GIR)
U (Spring)
5-1-6 units. REST
1.000 Computer Programming for Scientific and Engineering Applications
Prereq: None. Coreq: 18.03
U (Fall)
3-2-7 units. REST

Presents the fundamentals of computing and computer programming (procedural and object-oriented programming) in an engineering context. Introduces logical operations, floating-point arithmetic, data structures, induction, iteration, and recursion. Computational methods for interpolation, regression, root finding, sorting, searching, and the solution of linear systems of equations and ordinary differential equations. Control of sensors and visualization of scientific data. Draws examples from engineering and scientific applications. Students use the MATLAB programming environment to complete weekly assignments.

R. Juanes

1.001 Engineering Computation and Data Science
Subject meets with 1.00
Prereq: Calculus I (GIR)
G (Spring)
5-1-6 units

Presents fundamentals of computing and programming in an engineering context with an emphasis on data science. Introduces basics of web computing, data structures, and techniques for data analysis. Includes filtering, linear regression, simple machine learning (clustering and classifiers), and visualization. Surveys techniques for ingesting, processing, analyzing, and visualizing engineering data from a range of fields, including geo-spatial, environment, infrastructure, city dynamics, and numerical experiments. Students use JavaScript and HTML5 programming language to complete weekly assignments. Students taking graduate version complete additional assignments.

J. Williams

1.007 Big Engineering: Small Solutions with a Large Impact
Prereq: None
U (Spring; first half of term)
3-0-3 units

Provides a practical introduction to key topics, current research and innovative methods in the diverse field of civil and environmental engineering. Discusses career opportunities, innovation, and entrepreneurship. Under faculty supervision, students work on projects in areas such as renewable energy, sustainable design, food security, climate change, and transportation. Projects focus on design of novel solutions to grand challenges related to infrastructure, systems and the environment, and include elements of the different areas to demonstrate the interconnectedness of the discipline. Preference to first-year students and Course 1 sophomores.

B. Marelli

1.010 Uncertainty in Engineering
Prereq: Calculus II (GIR)
U (Fall)
5-0-7 units

Introduces probability and statistics with an emphasis on understanding, quantifying, and modeling uncertainty. Topics include events and their probability, the total probability and Bayes' theorems, discrete and continuous random variables and vectors, covariance, correlations, and conditional analysis. Random sampling, estimation of distribution parameters (method of moments, maximum likelihood, Bayesian estimation), and simple and multiple linear regression. Concepts illustrated with examples from various areas of engineering and everyday life. Integrates applications with statistical computing and graphics.

S. Saavedra

1.011 Project Evaluation and Management
Prereq: None
U (Spring)
3-1-8 units

Develops skills to evaluate a project or program using economic, environmental, and equity metrics, and to plan, execute and manage its progress to completion. Introduces students to engineering projects that are typically large-scale and long-lived, and involve many economic, financial, social and environmental factors. Covers net present value analysis, life-cycle costing, and benefit-cost analysis. Culminates in a term project in which small teams study a historical or prospective project of their choosing. Instruction and practice in oral and written communication provided.

J. Sussman
1.013 Senior Civil and Environmental Engineering Design
Prereq: Permission of instructor
U (Spring)
2-6-4 units

Students engage with faculty around a topic of mutual interest, building on the knowledge/skills gained throughout their program. Synthesizes prior coursework and experiences through a semester-long design project and related assignments. Students form teams to work on projects of their choosing, focusing in depth on the diverse areas within civil and environmental engineering. Teams demonstrate creativity in applying theories and methodologies while considering their project’s technical, environmental and social feasibility. Includes lectures on a variety of related engineering concepts, as well as scholarship and engineering practice and ethics. Provides instruction and practice in oral and written communication.

H. Hemond

1.015[J] Design of Electromechanical Robotic Systems
Same subject as 2.017[J]
Prereq: 2.003[J] or 2.03; Coreq: 2.005, 2.05 and 2.051, or 2.016; 2.671
U (Spring)
3-3-6 units. 1/2 Institute LAB

See description under subject 2.017[J]. Enrollment may be limited due to laboratory capacity.

F. S. Hover, J. J. Leonard

1.016 Design for Complex Environmental Issues: Building Solutions and Communicating Ideas
Prereq: None
U (Spring)
3-1-5 units

Students work in small groups, under the guidance of researchers from MIT, to pursue specific aspects of the year’s Terrascope problem. Teams design and build prototypes, graphic displays and other tools to communicate their findings and display them in a Bazaar of Ideas open to the MIT community. Some teams develop particular solutions, others work to provide deeper understanding of the issues, and others focus on ways to communicate these ideas with the general public. Students’ work is evaluated by independent experts. Offers students an opportunity to develop ideas from the fall semester and to work in labs across MIT. Limited to first-year students.

C. Harvey

Same subject as 7.30A[J], 12.031A[J]
Prereq: None
U (Fall; first half of term)
2-0-4 units

Fundamentals of ecology, considering Earth as an integrated dynamic living system. Coevolution of the biosphere and geosphere, biogeochemical cycles, metabolic diversity, primary productivity, competition and the niche, trophic dynamics and food webs, population growth and limiting factors. Combination of 1.018A[J] and 1.018B[J] counts as REST subject.

O. Cordero, M. Follows

Same subject as 7.30B[J], 12.031B[J]
Prereq: 1.018A[J]
U (Fall; second half of term)
2-0-4 units


O. Cordero, M. Follows

1.020 Principles of Energy and Water Sustainability
Prereq: Physics I (GIR); Coreq: 18.03 or permission of instructor
U (Spring)
3-2-7 units

Introduces a systems approach to modeling, analysis, and decision-making problems for water and energy sustainability; formulation of models based on physical, environmental, social, and economic principles; and economic evaluation of design. Covers applications of mass balance, energy balance, and economic and lifecycle concepts. Uses numerical models to integrate concepts and to assess environmental impacts of human activities.

S. Amin

1.021 Introduction to Modeling and Simulation
Engineering School-Wide Elective Subject.
Offered under: 1.021, 3.021, 10.333, 22.00
Prereq: 18.03, 3.016, or permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: U (Spring)
4-0-8 units. REST

See description under subject 3.021.

M. Buehler, R. Taylor
1.022 Urban Networks
Prereq: 1.00 or 1.000; 1.010
U (Fall; second half of term)
3-0-3 units
Introduces the structure and evolution of networks with examples from engineering, applied mathematics, computer science, and statistical physics. Includes analysis of real world datasets focused on identifying important nodes in networks, detecting communities, tracing network flows, and modeling and visualization of spatial networks.
M. Gonzalez

1.032 Advanced Soil Mechanics
Subject meets with 1.361
Prereq: 1.010, 1.011, 1.036
U (Fall; first half of term)
3-0-6 units
Covers topics in the characterization and nature of soils as multi-phase materials; the principle of effective stress; hydraulic conductivity and groundwater seepage; shear strength and stability analyses; stress-deformation properties, consolidation theory and calculation of settlements for clays and sands. Students taking graduate version complete additional assignments.
A. Whittle

1.035 Multiscale Characterization of Materials
Prereq: 1.050, 18.03
U (Spring)
3-3-6 units
Introduces the structure and properties of natural and manufactured building materials. Emphasizes effects of molecular and nanoscopic structure and interactions on macroscopic material behavior. Focuses on design of biological and artificial structural materials. Discusses material aspects of sustainable development. Includes durability, deterioration mechanisms, and damage assessment of building materials. Presents principles of experimental characterization techniques. Explores spectroscopic, microscopic and mechanical approaches to characterize structure and properties from molecular up to the macroscopic scale. In laboratory and in-field sessions, students design and implement experimental approaches to characterize natural and building materials and study their interaction with the environment.
F. Ulm

1.036 Structural Mechanics and Design
Prereq: 1.035, 1.050
U (Spring)
3-1-8 units
Familiarizes students with structural systems, loads, and basis for structural design, including analysis of determinate and indeterminate structures (trusses, beams, frames, cables, and arches). Covers mechanical properties of construction materials, including concrete, steel, and composites. Studies concrete and steel structures through application of principles of structural mechanics. Evaluates behavior and design of reinforced concrete structural elements using limit strength design and serviceability principles. Introduces plastic analysis and design, and load factor design of structural steel members and connections. Team project emphasizes material covered through behavior and problem-based learning.
O. Buyukozturk

1.037 Soil Mechanics and Geotechnical Design
Prereq: None
U (Spring)
3-2-7 units
Provides an introduction to soils as engineering materials, including classification and characterization, pore pressures and seepage, principles of effective stress and consolidation, deformation, and shear strength properties. Surveys analysis methods, with a focus on slope stability, limiting earth pressures and bearing capacity, and settlements of foundations. Examines applications in the design of earth dams, earth retaining systems, foundations, and staged construction processes.
A. Whittle

1.041 Transportation Systems Modeling
Prereq: 1.00 or 1.000; 1.010
U (Spring)
3-1-8 units
Introduces basic concepts of transportation systems modeling, data analysis and visualization techniques. Covers fundamental analytical and simulation-based methodologies. Topics include time-space diagrams, cumulative plots, queueing theory, network science, data analysis, and their applications. Provides students with an understanding of the current challenges and opportunities in different areas of transportation.
C. Osorio
Same subject as 2.66[J], 4.42[J]
Prereq: Physics I (GIR), Calculus II (GIR)
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: U (Fall)
3-2-7 units. REST
See description under subject 4.42[J].
L. R. Glicksman

1.050 Solid Mechanics
Prereq: Physics I (GIR); Coreq: Calculus II (GIR)
U (Fall)
3-2-7 units. REST
Basic principles of mechanics to describe the behavior of materials, structures and fluids. Dimensional analysis, conservation of momentum, static equilibrium, stress and stress states, hydrostatics, moments and forces. Material and structural strength criteria. Deformation and strain. Conservation of energy in solid mechanics, elasticity and elasticity bounds. Energy dissipation, plasticity and fracture. Open-ended geotechnical and structural engineering studio exercises and experiments with natural and man-made physical systems.
F. J. Ulm

1.053[J] Dynamics and Control I
Same subject as 2.003[J]
Prereq: Physics II; Coreq: 18.03 or 2.087
U (Fall, Spring)
4-1-7 units. REST
See description under subject 2.003[J].
J. K. Vandiver, N. C. Makris, N. M. Patrikalakis, T. Peacock, D. Gossard, K. Turitsyn

1.054 Mechanics and Design of Concrete Structures
Subject meets with 1.541
Prereq: 1.035
U (Fall)
3-0-9 units
Studies strength and deformation of concrete under various states of stress; failure criteria; concrete plasticity; and fracture mechanics concepts. Topics include fundamental behavior of reinforced concrete structural systems and their members; basis for design and code constraints; high-performance concrete materials and their use in innovative design solutions; and yield line theory for slabs. Uses behavior models and nonlinear analysis. Covers complex systems, including bridge structures, concrete shells, and containments. Students taking graduate version complete additional assignments.
O. Buyukozturk

1.056[J] Building Structural Systems I
Same subject as 4.440[J]
Subject meets with 4.462
Prereq: Calculus II (GIR)
U (Spring)
3-3-6 units. REST
See description under subject 4.440[J].
J. Ochsendorf

1.058 Structural Dynamics & Vibrations
Subject meets with 1.581[J], 2.060[J], 16.221[J]
Prereq: Permission of instructor
U (Fall)
3-1-8 units
Single- and multiple-degree-of-freedom vibration problems, using matrix formulation and normal mode superposition methods. Time and frequency domain solution techniques including convolution and Fourier transforms. Applications to vibration isolation, damping treatment, and dynamic absorbers. Analysis of continuous systems by exact and approximate methods. Applications to buildings, ships, aircraft and offshore structures. Vibration measurement and analysis techniques. Students should possess basic knowledge in structural mechanics and in linear algebra. Students taking graduate version complete additional assignments.
E. Kausel

1.060A Fluid Mechanics I
Prereq: Permission of instructor or Coreq: 18.03
U (Fall; first half of term)
2-1-3 units
B. Marelli

1.060B Fluid Mechanics II
Prereq: 1.060A
U (Fall; second half of term)
2-1-3 units
B. Marelli
1.061 Transport Processes in the Environment
Subject meets with 1.61
Prereq: 1.060B
U (Fall)
3-1-8 units
Introduction to mass transport in environmental flows, with emphasis on river and lake systems. Covers derivation and solutions to the differential form of mass conservation equations, hydraulic models for environmental systems, residence time distribution, molecular and turbulent diffusion for continuous and point sources, boundary layers, dissolution, bed-water exchange, air-water exchange, and particle transport. Meets with 1.061A first half of term. Students taking graduate version complete additional assignments.
H. M. Nepf

1.061A Transport Processes in the Environment I
Prereq: 1.060A
U (Fall; first half of term)
2-1-3 units
Introduction to mass transport in environmental flows. Covers derivation and solution to the differential form of mass conservation, hydraulic models for environmental systems, residence time distribution, and molecular and turbulent diffusion for continuous and point sources. Meets with 1.061 first half of term.
H. Nepf

1.062[J] Nonlinear Dynamics: Continuum Systems
Same subject as 12.207[J], 18.354[J]
Subject meets with 18.3541
Prereq: 18.03 or 18.034; Physics II (GIR)
U (Spring)
3-0-9 units
See description under subject 18.354[J].
P. Pearce

1.064 Physical Limnology
Subject meets with 1.64
Prereq: 1.061
U (Spring)
Not offered regularly; consult department
3-0-9 units
Provides an introduction to physical processes occurring in lakes and shallow surface water systems with emphasis on mechanisms affecting fate and transport. Topics include internal waves, differential heating and cooling, boundary mixing, turbulent mixing, and influence of vegetation. Begins with a review of Navier-Stokes equation. Students taking graduate version complete additional assignments.
H. M. Nepf

1.068 Nonlinear Dynamics and Turbulence
Subject meets with 1.686[J], 2.033[J], 18.358[J]
Prereq: Permission of instructor
Acad Year 2016-2017: U (Spring)
Acad Year 2017-2018: Not offered
3-0-9 units
Reviews theoretical notions of nonlinear dynamics, instabilities, and waves with applications in fluid dynamics. Discusses hydrodynamic instabilities leading to flow destabilization and transition to turbulence. Focuses on physical turbulence and mixing from homogenous isotropic turbulence. Also covers topics such as rotating and stratified flows as they arise in the environment, wave-turbulence, and point source turbulent flows. Students taking graduate version complete additional assignments.
L. Bourouiba

1.070A[J] Introduction to Hydrology and Water Resources
Same subject as 12.320A[J]
Prereq: 1.060A; Coreq: 1.061A, 1.106
U (Fall; first half of term)
2-0-4 units
Water in the environment; Water resource systems; The hydrologic cycle at its role in the climate system; Surface water and energy balance; evaporation and transpiration through vegetation; Precipitation formation, infiltration, storm runoff, and flood processes; Groundwater aquifers, subsurface flow and the hydraulics of wells.
D. Entekhabi
1.070B[J] Introduction to Hydrology Modeling
Same subject as 12.320B[J]
Prereq: 1.070A[J]
U (Fall; second half of term)
2-0-4 units
Develops understanding of numerical modeling of aquifers, groundwater flow and contaminant transport, as well as uncertainty and risk analysis for water resources. 
D. Entekhabi

1.071[J] Global Change Science
Same subject as 12.300[J]
Prereq: 18.03
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: U (Fall)
3-0-9 units
Introduces the basic relevant principles and concepts in atmospheric physics, climate dynamics, biogeochemistry, and water and energy balance at the land-atmosphere boundary, through an examination of two current problems in the global environment: carbon dioxide and global warming; and tropical deforestation and regional climate. An introduction to global environmental problems for students in basic sciences and engineering.
E. A. B. Eltahir

1.072 Groundwater Hydrology
Subject meets with 1.72
Prereq: 1.061
U (Fall)
3-1-8 units
Presents the fundamentals of subsurface flow and transport, emphasizing the role of groundwater in the hydrologic cycle, the relation of groundwater flow to geologic structure, and the management of contaminated groundwater. Topics include Darcy equation, flow nets, mass conservation, the aquifer flow equation, heterogeneity and anisotropy, storage properties, regional circulation, unsaturated flow, recharge, stream-aquifer interaction, well hydraulics, flow through fractured rock, numerical models, groundwater quality, contaminant transport processes, dispersion, decay, and adsorption. Includes laboratory and computer demonstrations. Students taking graduate version complete additional assignments.
C. Harvey

1.073 Introduction to Environmental Data Analysis
Prereq: 1.010
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: U (Spring; first half of term)
2-0-4 units
Covers theory and practical methods for the analysis of univariate data sets. Topics include basics of statistical inference, analysis of trends and stationarity; Gaussian stochastic processes, covariance and correlation analysis, and introduction to spectral analysis. Students analyze data collected from the civil, environment, and systems domains.
E. Eltahir

1.074 Multivariate Data Analysis
Prereq: 1.010
U (Spring; second half of term)
2-0-4 units
Introduction to statistical multivariate analysis methods and their applications to analyze data and mathematical models. Topics include sampling, experimental design, regression analysis, specification testing, dimension reduction, categorical data analysis, classification and clustering.
Staff

1.075 Water Resource Systems (New)
Subject meets with 1.731
Prereq: 1.070B[J] or permission of instructor
U (Fall)
3-0-9 units
Surveys optimization and simulation methods for management of water resources. Case studies illustrate linear, quadratic, nonlinear programming and real-time control. Applications include river basin planning, irrigation and agriculture, reservoir operations, capacity expansion, assimilation of remote sensing data, and sustainable resource development. Students taking graduate version complete additional assignments.
D. McLaughlin
1.078 Introduction to Soil Science (New)
Subject meets with 1.78
Prereq: None
U (Fall)
3-1-8 units

Presents the physical, chemical, biological and genetic properties of soils, their global distribution, and response to management. Emphasizes factors controlling soil development, plant productivity, and the fate, cycling and bioavailability of soil nutrients and pollutants. Introduces Earth’s different soil types and their classification; links characteristics with contemporary and historic issues surrounding natural and managed soil systems. Topics include soil carbon cycling, water and fertilizer management, and challenges associated with soil salinity-sodicity, erosion, and pollution. Includes field trips to local sites to examine soil physical properties, classification, and function. Introductory biology and chemistry are recommended prerequisites. Students taking graduate version complete additional assignments.
B. Kocar

1.080A Environmental Chemistry I
Prereq: Chemistry (GIR)
U (Spring; first half of term)
2-0-4 units

Introduction to environmental chemistry with a focus on using thermodynamics to understand processes governing chemical behaviors in natural and engineered systems. Topics include vaporization, gas-solution partitioning, salt and mineral dissolution/precipitation, acid-base chemistry, metal complexation, adsorption via ion exchange, and absorption within natural organic matter and organism tissues. Process formulations are combined in box models to compare with observations.
P. M. Gschwend

1.080B Environmental Chemistry II
Prereq: 1.080A
U (Spring; second half of term)
2-0-4 units

Intermediate topics in environmental chemistry requiring kinetics to understand processes governing biogeochemical behaviors in natural and engineered systems. Topics include radiochemistry, redox chemistry, surface chemistry and surface complexation. Introduction to geochemical modeling using reactive transport software; process formulations are combined in chemical fate models to compare with observations as a function of space and time.
J. Kroll

1.081[J] Environmental Cancer Risks, Prevention, and Therapy
Same subject as 20.104[J]
Prereq: Calculus II (GIR), Biology (GIR), Chemistry (GIR)
U (Spring)
3-0-9 units

See description under subject 20.104[J].
W. Thilly, R. McCunney

1.082 Ethics for Engineers
Engineering School-Wide Elective Subject.
Offered under: 1.082, 2.900, 6.904, 10.01, 22.014
Prereq: None
U (Fall, Spring)
2-0-4 units

See description under subject 10.01.
D. Doneson, B. L. Trout

1.084[J] Systems Microbiology
Same subject as 20.106[J]
Prereq: Chemistry (GIR), Biology (GIR)
U (Fall)
3-0-9 units

See description under subject 20.106[J].
E. Alm, J. Niles

1.085[J] Air Pollution
Same subject as 12.336[J]
Prereq: 18.03
U (Fall)
3-0-9 units

Provides a working knowledge of basic air quality issues, with emphasis on a multidisciplinary approach to investigating the sources and effects of pollution. Topics include emission sources; atmospheric chemistry and removal processes; meteorological phenomena and their impact on pollution transport at local to global scales; air pollution control technologies; health effects; and regulatory standards. Discusses regional and global issues, such as acid rain, ozone depletion and air quality connections to climate change.
C. Heald
1.089 Environmental Microbiology
Subject meets with 1.89
Prereq: Biology (GIR)
U (Spring)
3-0-9 units
Provides a general introduction to the diverse roles of microorganisms in natural and artificial environments. Topics include energetics and growth, evolution and gene flow, population and community dynamics, water and soil microbiology, biogeochemical cycling, and microorganisms in biodegradation and bioremediation. 7.014 recommended as prerequisite; students taking graduate version complete additional assignments. Meets with 1.089A first half of term.
M. Polz, O. Cordero

1.089A Environmental Microbiology I (New)
Prereq: Biology (GIR) or permission of instructor
U (Spring; first half of term)
3-0-3 units
Provides a general introduction to the diverse roles of microorganisms in natural and artificial environments. Topics include energetics, and growth; metabolic interactions; water and soil microbiology; biogeochemical cycling; microbial diversity. 7.014 recommended as prerequisite. Meets with 1.089 first half of term.
M. Polz, O. Cordero

1.091 Traveling Research Environmental eXperience (TREX): Fieldwork
Prereq: Permission of instructor
U (IAP)
1-2-0 units
Introduction to environmental fieldwork and research, with a focus on data collection and analysis. Subject spans three weeks, including two weeks of fieldwork, and involves one or more projects central to environmental science and engineering. Location varies year-to-year, though recent projects have focused on the island of Hawaii. Limited to Course 1 students.
B. Kocar

1.092 Traveling Research Environmental eXperience (TREX): Fieldwork Analysis and Communication
Prereq: 1.091
U (Spring)
1-3-5 units
Building on fieldwork and research conducted in 1.091 over IAP, students focus on interpretation of results and research in support of the fieldwork, with instruction and practice in oral and written communication. Includes a survey of the relevant peer-reviewed literature; laboratory measurements of field samples and/or instrumental response; data analysis and interpretation; and dissemination of results. Culminates in presentation of research project(s), and write-ups of the research in manuscript form. Sequence of 1.091 and 1.092 must be completed in consecutive terms. Limited to Course 1 majors and minors.
B. Kocar

1.095 Teaching Practicum in Civil and Environmental Engineering
Prereq: Permission of instructor
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.
Students work as unpaid laboratory, tutorial, or classroom assistants under supervision of a faculty member. Limited to Undergraduate Teaching Fellows and graders in Course 1.
Staff

1.097 Introduction to Civil and Environmental Engineering Research
Prereq: None
U (IAP)
1-5-0 units
Students work one-on-one with a CEE graduate student or postdoc mentor on a project that aligns with their research interests. Previous project topics include transportation networks, structural mechanics, sediment transport, climate science, and microbial ecology. Includes weekly seminar-style talks. Intended for first-year students.
Staff
Undergraduate Laboratory Subjects

1.101 Introduction to Civil and Environmental Engineering Design I
Prereq: None
U (Fall)
0-4-2 units. 1/2 Institute LAB
Introduces the creative design process in the context of civil and environmental engineering. Emphasizes the idea-to-product trajectory: identification of a design question/problem, evaluation of requirements/constraints set by the application and/or client, and implementation into a concrete product deliverable. Fosters active learning through open-ended, student-driven projects in which teams apply the design process to a design/planning problem. In labs, students design and build a working model or an experiment that addresses a specific engineering aspect of their project. In addition to written and oral presentations, students start a web-based portfolio. Enrollment limited; preference to Course 1 majors and minors.
P. Reis

1.102 Introduction to Civil and Environmental Engineering Design II
Prereq: Physics II (GIR); or Coreq: 1.060B and permission of instructor
U (Spring)
1-3-2 units. 1/2 Institute LAB
Project-oriented subject focused on the principles and practice of engineering design. Emphasis on construction and deployment of designs, plus performance testing used to determine if designs behave as expected. Includes a major team project involving use and application of sensors, as well as environmentally-friendly, and energy-effective or energy-producing designs. Develops practical, teamwork and communication skills. Enrollment limited; preference to Course 1 majors and minors.
A. Masic

1.106 Environmental Fluid Transport Processes and Hydrology Laboratory
Prereq: None. Coreq: 1.061A, 1.070A
U (Fall)
0-4-2 units. 1/2 Institute LAB
Fundamentals of mass transport and flow measurements in the context of environmental systems. Topics include measurement uncertainty, propagation of error, diffusion, dispersion, air-water exchange, dissolution, gravity currents, particle transport, and transport in porous media. Includes formal lab reports. Enrollment limited; preference to 1-ENG.
H. Nepf, D. Entekhabi

1.107 Environmental Chemistry and Biology Laboratory
Prereq: 1.018A or permission of instructor; Coreq: 1.080A
U (Spring)
0-4-2 units. 1/2 Institute LAB
Laboratory and field techniques in biogeochemistry and environmental engineering and their application to the understanding of natural and engineered ecosystems. Exercises demonstrate data acquisition and modeling suited to identifying and quantifying physical, chemical, and biological processes that govern the effects of human activity on the functioning of natural systems and/or the efficacy of engineered approaches to environmental problems. Applications include chemical and biological remediation, measurement of contaminants, and detection of biogeochemical activity in natural environments. An independently designed final project is required. Enrollment limited; preference to 1-ENG.
P. Gschwend, B. Kocar

Engineering Information Systems and Computation

1.124 Software and Computation for Simulation
Same subject as 2.091
Prereq: 1.00 or permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units
Modern software development techniques and algorithms for engineering computation. Hands-on investigation of computational and software techniques for simulating engineering systems, such as sensor networks, traffic networks, and discrete simulation of materials using atomistic and particle methods. Covers data structures and algorithms for modeling, analysis, and visualization in the setting of multi-core and distributed computing. Treatment of basic topics, such as queuing, sorting and search algorithms, and more advanced numerical techniques based on state machines and distributed agents. Foundation for in-depth exploration of image processing, optimization, finite element and particle methods, computational materials, discrete element methods, and network methods. Knowledge of an object-oriented language required.
J. R. Williams
1.125 Architecting & Engineering Software Systems  
Prereq: 1.00, 1.124[J], or permission of instructor  
G (Fall)  
3-0-9 units  
Software architecting and design of software-intensive systems.  
Targeted at future CTOs who must understand both the business and  
technical issues involved in architecting enterprise-scale systems.  
Student teams confront technically challenging problems. Lectures  
and readings cover core database, XML, web server components and  
browser issues in a distributed web service environment. Enrollment  
limited.  
J. Williams

1.126[J] Pattern Recognition and Analysis  
Same subject as MAS.622[J]  
Prereq: Permission of instructor  
G (Fall)  
Not offered regularly; consult department  
3-0-9 units  
See description under subject MAS.622[J]. Limited to 20.  
R. W. Picard

1.128[J] Computational Geometry  
Same subject as 2.089[J]  
Prereq: Permission of instructor  
G (Spring)  
Not offered regularly; consult department  
3-0-9 units  
See description under subject 2.089[J].  
N. M. Patrikalakis, D. C. Gossard

Engineering Systems, Economics, and Optimization

1.142[J] Robust Modeling, Optimization, and Computation  
Same subject as 15.094[J]  
Prereq: 18.06 or permission of instructor  
G (Spring)  
4-0-8 units  
See description under subject 15.094[J].  
D. Bertsimas

1.146 Engineering Systems Analysis for Design  
Engineering School-Wide Elective Subject.  
Offered under: 1.146, 16.861, IDS.332  
Subject meets with IDS.333  
Prereq: Permission of instructor  
G (Fall)  
3-0-9 units  
See description under subject IDS.332.  
R. de Neufville

Engineering Risk Assessment and Probabilistic Analysis

1.151 Probability and Statistics in Engineering  
Prereq: Permission of instructor  
G (Spring)  
3-0-9 units  
Introduces probability and statistics for engineering applications.  
Topics in probability include events and their probability, Total  
Probability and Bayes’ Theorems, discrete and continuous random  
variables and vectors, Bernoulli Trial Sequence and Poisson point  
process, functions of random variables and vectors and conditional  
uncertainty analysis using full-distribution and second-moment  
uncertainty representation. Topics in statistics include estimation  
of distribution parameters, hypothesis testing, and simple linear  
regression. Concepts illustrated with examples from various areas of  
engineering and everyday life.  
D. Veneziano
1.153 Transportation Policy, the Environment, and Livable Communities
Subject meets with 1.253[J], 11.543[J]
Prereq: 1.011
U (Spring)
3-0-9 units
Examines the economic and political conflict between transportation and the environment. Investigates the role of government regulation, green business and transportation policy as a facilitator of economic development and environmental sustainability. Analyzes a variety of international policy problems, including government-business relations, the role of interest groups, non-governmental organizations, and the public and media in the regulation of the automobile; sustainable development; global warming; politics of risk and siting of transport facilities; environmental justice; equity; as well as transportation and public health in the urban metropolis. Provides students with an opportunity to apply transportation and planning methods to develop policy alternatives in the context of environmental politics. Students taking graduate version complete additional assignments.
J. Coughlin

1.200[J] Transportation Systems Analysis: Performance and Optimization
Same subject as 11.544[J]
Prereq: 1.010, permission of instructor
G (Fall)
3-1-8 units
Problem-motivated introduction to methods, models and tools for the analysis and design of transportation networks including their planning, operations and control. Capacity of critical elements of transportation networks. Traffic flows and deterministic and probabilistic delay models. Formulation of optimization models for planning and scheduling of freight, transit and airline systems, and their solution using software packages. User- and system-optimal traffic assignment. Control of traffic flows on highways, urban grids, and airspace.
C. Osorio

1.201[J] Transportation Systems Analysis: Demand and Economics
Same subject as 11.545[J]
Prereq: Permission of instructor
G (Fall)
3-1-8 units
Covers the key principles governing transportation systems planning and management. Introduces the microeconomic concepts central to transportation systems. Topics include economic theories of the firm, consumer, and market, demand models, discrete choice analysis, cost models and production functions, and pricing theory. Applications to transportation systems - including congestion pricing, technological change, resource allocation, market structure and regulation, revenue forecasting, public and private transportation finance, and project evaluation - cover urban passenger transportation, freight, maritime, aviation, and intelligent transportation systems.
Staff

1.202 Demand Modeling
Prereq: 1.201[J] or permission of instructor
G (Spring)
3-1-8 units
Theory and application of modeling and statistical methods for analysis and forecasting of demand for facilities, services, and products. Topics include: review of probability and statistics, estimation and testing of linear regression models, theory of individual choice behavior, derivation, estimation, and testing of discrete choice models (including logit, nested logit, GEV, probit, and mixture models), estimation under various sample designs and data collection methods (including revealed and stated preferences), sampling, aggregate forecasting methods, and iterative proportional fitting and related methods. Lectures reinforced with case studies, which require specification, estimation, testing, and analysis of models using data sets from actual applications.
Staff
1.203[J] Logistical and Transportation Planning Methods
Same subject as 15.073[J], 16.76[J]
Prereq: 6.041B
G (Spring)
3-0-9 units
Quantitative techniques of operations research with emphasis on applications in transportation systems analysis (urban, air, ocean, highway, and pickup and delivery systems) and in the planning and design of logistically oriented urban service systems (e.g., fire and police departments, emergency medical services, and emergency repair services). Unified study of functions of random variables, geometrical probability, multi-server queuing theory, spatial location theory, network analysis and graph theory, and relevant methods of simulation. Computer exercises and discussions of implementation difficulties.
R. C. Larson, A. I. Barnett

1.204 Computer Modeling: From Human Mobility to Transportation Networks
Prereq: 1.001, 1.010; or permission of instructor
G (Spring)
3-0-9 units
Introduces methods for modeling individual travels at a country scale. Reviews basic concepts of data analysis, modeling, and visualization techniques. Topics include data mining to identify the structure inherent in daily behavior; introduction to fractals, random walks and methods to analyze trajectories. Algorithms to model and characterize complex networks, and their applications to daily commuting, air travels, and roads. Includes weekly open laptop exercises based on the data sets and methods from the research papers covered in class. Exposes students to the current challenges and opportunities in networks applied to human mobility.
M. C. Gonzalez

1.205 Advanced Demand Modeling
Prereq: 1.202 or permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3-0-9 units
Advanced theories and applications of models for analysis and forecasting of users’ behavior and demand for facilities, services, and products. Topics vary each year and typically include linear and nonlinear latent variable models, including structural equations and latent class models; estimation techniques with multiple data sources; joint discrete and continuous choice models; dynamic models; analysis of panel data; analysis of complex choices; estimation and forecasting with large choice sets; multidimensional probabilistic choice models; advanced choice models, including probit, logit mixtures, treatment of endogeneity, hybrid choice models, hidden Markov models, Monte Carlo simulation, Bayesian methods, survey design, sampling, model transferability, and use of stated preferences data. Term paper required.
M. E. Ben-Akiva

1.207 Computer Algorithms in Systems Engineering
Prereq: 1.001 or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units
Staff

1.208 Resilient Infrastructure Networks
Prereq: 1.151 or 6.431B; 15.093[J]
G (Fall)
3-0-9 units
S. Amin
1.231[J] Planning and Design of Airport Systems
Same subject as 16.781[J], IDS.670[J]
Prereq: Permission of instructor
Acad Year 2016-2017: G (Fall)
Acad Year 2017-2018: Not offered
3-0-9 units

Focuses on current practice, developing trends, and advanced concepts in airport design and planning. Considers economic, environmental, and other trade-offs related to airport location, as well as the impacts of emphasizing “green” measures. Includes an analysis of the effect of airline operations on airports. Topics include demand prediction, determination of airfield capacity, and estimation of levels of congestion; terminal design; the role of airports in the aviation and transportation system; access problems; optimal configuration of air transport networks and implications for airport development; and economics, financing, and institutional aspects. Special attention to international practice and developments.

R. de Neufville, A. R. Odonii

1.232[J] The Airline Industry
Same subject as 15.054[J], 16.71[J]
Prereq: None
G (Fall)
3-0-9 units

See description under subject 16.71[J].

P. P. Belobaba, A. I. Barnett, C. Barnhart, R. J. Hansman, T. A. Kochan

1.233[J] Air Transportation Operations Research
Same subject as 16.763[J]
Prereq: 16.71[J], 6.431, 15.093[J], or permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
3-0-9 units

See description under subject 16.763[J].

H. Balakrishnan, C. Barnhart, P. P. Belobaba

1.234[J] Airline Management
Same subject as 16.75[J]
Prereq: 16.71[J]
Acad Year 2016-2017: G (Spring)
Acad Year 2017-2018: Not offered
3-0-9 units

See description under subject 16.75[J].

P. P. Belobaba

1.251[J] Comparative Land Use and Transportation Planning
Same subject as 11.526[J]
Prereq: Permission of instructor
G (Spring)
3-0-9 units

See description under subject 11.526[J].

C. Zegras

1.252[J] Urban Transportation Planning
Same subject as 11.540[J]
Prereq: Permission of instructor
G (Fall)
3-0-9 units

Studies the history, policy, practice and politics of urban transportation. Covers the role of the federal, state, and local government and the MPO, public transit in the auto era, analysis of current trends and pattern breaks; analytical tools for transportation planning, traffic engineering and policy analysis; the contribution of transportation to air pollution, social costs and climate change; land use and transportation interactions; traffic and place making; bicycles, pedestrians, and traffic calming. Examples from the Boston area and from Bilbao.

F. Salvucci, M. Murgo

1.253[J] Transportation Policy, the Environment, and Livable Communities
Same subject as 11.543[J]
Subject meets with 1.153
Prereq: Permission of instructor
G (Spring)
3-0-9 units

Examines the economic and political conflict between transportation and the environment. Investigates the role of government regulation, green business and transportation policy as a facilitator of economic development and environmental sustainability. Analyzes a variety of international policy problems, including government-business relations, the role of interest groups, non-governmental organizations, and the public and media in the regulation of the automobile; sustainable development; global warming; politics of risk and siting of transport facilities; environmental justice; equity; as well as transportation and public health in the urban metropolis. Provides students with an opportunity to apply transportation and planning methods to develop policy alternatives in the context of environmental politics. Students taking graduate version complete additional assignments.

J. Coughlin
1.254 Transport Modeling Course
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units
Fosters practical experience with the concepts and approaches behind the analytical chain composed by GIS, 4-step planning, and traffic models. Study conducted in Greater Boston. Students develop road and street, pedestrian, and public transportation networks. Uses the latest Census Transportation Planning Products (CTPP) data, and Boston home travel survey to understand travel behavior and calibrate model. Final project involves the design of alternative futures for the metropolitan area with different transportation and land use policies.

Staff

1.258[J] Public Transportation Systems
Same subject as 11.541[J]
Prereq: 1.201[J] or permission of instructor
G (Spring)
3-0-9 units
Discusses evolution and role of urban public transportation modes, systems and services, focusing on bus and rail. Describes technological characteristics and their impacts on capacity, service quality, and cost. Current practice and new methods for data collection and analysis, performance monitoring, route and network design, frequency determination, and vehicle and crew scheduling. Effect of pricing policy and service quality on ridership. Methods for estimating costs associated with proposed service changes. Organizational models for delivering public transportation service including finance and operations.

Staff

1.260[J] Logistics Systems
Same subject as 15.770[J], IDS.730[J], SCM.260[J]
Prereq: Permission of instructor
G (Fall)
3-0-9 units
See description under subject SCM.260[J].
Y. Sheffi, C. Caplice

1.261[J] Case Studies in Logistics and Supply Chain Management
Same subject as 15.771[J], SCM.261[J]
Prereq: Permission of instructor
G (Spring)
3-0-6 units
See description under subject SCM.261[J].
J. Byrnes

1.265[J] Global Supply Chain Management
Same subject as 2.965[J], 15.765[J], SCM.265[J]
Prereq: 1.260[J], 1.261[J], 15.761, 15.778, or permission of instructor
G (Spring)
2-0-4 units
See description under subject SCM.265[J].
B. Arntzen

1.27 Studies in Transportation
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.
Individual advanced study of a topic in transportation systems, selected with the approval of the instructor.

Staff

Same subject as 15.764[J], IDS.250[J]
Prereq: 15.081[J] or 6.251[J], 6.436[J]; or permission of instructor
G (Spring)
3-0-9 units
Can be repeated for credit.
See description under subject 15.764[J].
D. Simchi-Levi, N. Trichakis, K. Zheng

1.273[J] Supply Chain Planning
Same subject as 15.762[J], IDS.735[J]
Prereq: 1.260[J] or 15.761
G (Spring)
2-0-4 units
See description under subject 15.762[J].

Staff

1.274[J] Manufacturing System and Supply Chain Design
Same subject as 15.763[J], IDS.736[J]
Prereq: 1.260[J], 15.761, or 15.778
G (Spring)
2-0-4 units
See description under subject 15.763[J].
S. C. Graves, D. Simchi-Levi
1.275[J] Business and Operations Analytics  
Same subject as IDS.305[J]  
Prereq: Permission of instructor  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (Spring; first half of term)  
2-0-4 units  
See description under subject IDS.305[J].  
D. Simchi-Levi

1.284[J] Analyzing and Accounting for Regional Economic Change  
Same subject as 11.481[J]  
Prereq: 14.03, 14.04  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (Spring)  
3-0-9 units  
See description under subject 11.481[J].  
Staff

1.285[J] Regional Socioeconomic Impact Analyses and Modeling  
Same subject as 11.482[J]  
Prereq: 11.481[J] or permission of instructor  
G (Fall)  
Not offered regularly; consult department  
2-1-9 units  
See description under subject 11.482[J].  
K. R. Polenske

Same subject as 11.477[J]  
Subject meets with 11.165  
Prereq: 11.203, 14.01, or permission of instructor  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (Fall)  
3-0-9 units  
See description under subject 11.477[J].  
D. Hsu

Geoenvironmental and Geotechnical Engineering

1.322 Soil Behavior  
Prereq: 1.361  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (Spring)  
4-0-8 units  
Detailed study of soil properties with emphasis on interpretation of field and laboratory test data and their use in soft-ground construction engineering. Includes: consolidation and secondary compression; basic strength principles; stress-strain strength behavior of clays, emphasizing effects of sample disturbance, anisotropy, and strain rate; strength and compression of granular soils; and engineering properties of compacted soils. Some knowledge of field and laboratory testing assumed; 1.37 desirable.  
A. J. Whittle

1.331 Advanced Soil Dynamics  
Prereq: Permission of Instructor  
G (Spring)  
Not offered regularly; consult department  
3-0-9 units  
E. Kausel

1.351 Theoretical Soil Mechanics  
Prereq: 1.361  
Acad Year 2016-2017: G (Spring)  
Acad Year 2017-2018: Not offered  
3-0-9 units  
A. J. Whittle
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Prerequisites</th>
<th>Credits</th>
<th>Description</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.361</td>
<td>Advanced Soil Mechanics</td>
<td>Subject meets with 1.032, Prereq: 1.036, G (Fall; first half of term)</td>
<td>3-0-6</td>
<td>Covers topics in the characterization and nature of soils as multiphase materials; the principle of effective stress; hydraulic conductivity and groundwater seepage; shear strength and stability analyses; stress-deformation properties, consolidation theory and calculation of settlements for clays and sands.</td>
<td>A. Whittle</td>
</tr>
<tr>
<td>1.364</td>
<td>Advanced Geotechnical Engineering</td>
<td>Prereq: 1.361, G (Fall; second half of term)</td>
<td>3-0-6</td>
<td>Methodology for site characterization and geotechnical aspects of the design and construction of foundation systems. Topics include site investigation (with emphasis on in situ testing), shallow (footings and raftings) and deep (piles and caissons) foundations, excavation support systems, groundwater control, slope stability, soil improvement (compaction, soil reinforcement, etc.), and construction monitoring.</td>
<td>A. Whittle</td>
</tr>
<tr>
<td>1.37</td>
<td>Geotechnical Measurements and Exploration</td>
<td>Prereq: 1.035, G (Fall)</td>
<td>3-4-2</td>
<td>Application of testing principles to the measurement of fundamental aspects of soil behavior from classification to engineering properties. Emphasis on rigorous techniques to measure mechanical behavior under various boundary conditions. Exposure to error estimation, research devices, geotechnical field exploration, and in situ testing. Extensive laboratory experiments to explore geotechnical test equipment and techniques. Laboratory use of testing automation and electronic instrumentation. Experiments include data analysis, evaluation, and presentation.</td>
<td>Staff</td>
</tr>
<tr>
<td>1.38</td>
<td>Engineering Geology</td>
<td>Prereq: Permission of instructor, G (Fall)</td>
<td>3-1-8</td>
<td>Studies the effect of geologic features and processes on constructed facilities; interaction between the geologic environment and man-made structures, and human activities in general. Planning of subsurface exploration. Engineering geologic characterization of soil and rock, including joint surveys and aspects of sediments and residual soils. Laboratory on basic geologic identification and mapping techniques. Extensive reading of case histories. Field trip.</td>
<td>H. H. Einstein</td>
</tr>
<tr>
<td>1.381</td>
<td>Rock Mechanics</td>
<td>Prereq: 1.38, 1.361, Acad Year 2016-2017: G (Spring), Acad Year 2017-2018: Not offered</td>
<td>3-0-9</td>
<td>Introduces theoretical and experimental aspects of rock mechanics and prepares students for rock engineering. Includes review of laboratory and field testing; empirical and analytical methods for describing strength, deformability and conductivity of intact rock and rock masses; fracture mechanics and mechanics of discontinua, including flow through discontinua and hydraulic fracturing; and design and analysis of rock slopes and foundations on rock. Also discusses blasting design. Includes term paper/term project.</td>
<td>H. H. Einstein</td>
</tr>
<tr>
<td>1.383</td>
<td>Underground Construction</td>
<td>Prereq: 1.361, 1.38, or permission of instructor, Acad Year 2016-2017: Not offered, Acad Year 2017-2018: G (Spring)</td>
<td>3-0-6</td>
<td>Provides familiarization with the most important aspects of planning, analysis, design, and construction of underground structures in soil and rock. Covers detailed engineering analysis and design, and major aspects of construction techniques and construction planning. Discusses general planning and economic problems. Includes a major design project involving all aspects of underground construction.</td>
<td>H. H. Einstein</td>
</tr>
</tbody>
</table>
1.39 Independent Study in Geotechnical Engineering  
Prereq: Permission of instructor  
G (Fall, Spring, Summer)  
Units arranged  
Can be repeated for credit.  

For graduate students desiring further individual study of topics in geotechnical engineering.  
Information: A. J. Whittle  

Construction Engineering and Management  

1.462[J] Entrepreneurship in Construction and Real Estate Development  
Same subject as 11.345[J]  
Prereq: Permission of instructor  
G (Fall; second half of term)  
2-0-4 units  

See description under subject 11.345[J].  
J. F. Kennedy  

1.463[J] Globalization and the Built Environment  
Same subject as 11.342[J]  
Prereq: Permission of instructor  
G (Fall)  
Not offered regularly; consult department  
2-0-4 units  

Addresses the importance and pervasiveness of globalization in Architecture, Engineering and Construction Companies (AEC Firms). Covers strategies for a presence in the global market and the importance of the global financial market in project financing, with a primary focus on infrastructure. Includes discussion of innovative approaches to marketing, partnering, risk management, finance, specialized delivery systems, and privatization.  
F. Moavenzadeh, D. Wolff  

1.472[J] Innovative Project Delivery in the Public and Private Sectors  
Same subject as 11.344[J]  
Prereq: Permission of instructor  
G (Spring; first half of term)  
2-0-4 units  

See description under subject 11.344[J].  
C. M. Gordon  

Materials and Structures  

1.541 Mechanics and Design of Concrete Structures  
Subject meets with 1.054  
Prereq: 1.035  
G (Fall)  
3-0-9 units  

Studies strength and deformation of concrete under various states of stress; failure criteria; concrete plasticity; and fracture mechanics concepts. Topics include fundamental behavior of reinforced concrete structural systems and their members; basis for design and code constraints; high-performance concrete materials and their use in innovative design solutions; and yield line theory for slabs. Uses behavior models and nonlinear analysis. Covers complex systems, including bridge structures, concrete shells, and containments. Students taking graduate version complete additional assignments.  
O. Buyukozturk  

1.545 Atomistic Modeling and Simulation of Materials and Structures  
Prereq: Permission of instructor  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (IAP)  
2-0-4 units  

Covers multiscale atomistic modeling and simulation methods, with focus on mechanical properties (elasticity, plasticity, creep, fracture, fatigue) of a range of materials (metals, ceramics, proteins, biological materials, biomaterials). Topics include mechanics of materials (energy principles, nano-/micromechanics, deformation mechanisms, size effects, hierarchical biological structures) and atomistic modeling (chemistry, interatomic potentials, visualization, data analysis, numerical methods, supercomputing, algorithms). Includes an interactive computational project.  
M. J. Buehler  

1.546 Statistical Mechanics of Biological Systems  
Prereq: Permission of instructor  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (IAP)  
2-0-4 units  

Develops the theory and methods of statistical mechanics of biological systems specifically relevant to environmental engineers. Intended for students with a background in biology, but without prior exposure to statistical mechanics.  
E. Alm
1.561 Motion-Based Design
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

Presents a rational basis for the preliminary design of motion-sensitive structures. Topics include: analytical and numerical techniques for establishing the optimal stiffness distribution, the role of damping in controlling motion, tuned mass dampers, base isolation systems, and an introduction to active structural control. Examples illustrating the application of the motion-based design paradigm to building structures subjected to wind and seismic excitation are discussed.

J. Ochsendorf

1.562 Structural Design Project I
Prereq: None
G (Fall)
3-0-9 units

Students work in teams to design a long-span structure, emphasizing conceptual design and advanced structural analysis. Subject covers structural systems and construction methods, interdisciplinary collaboration, design strategies for resistance to static and dynamic loading, and simplified calculation methods to validate numerical simulations. Emphasis on oral and visual communication of engineering concepts and students present their projects to leading engineers for feedback.

J. Ochsendorf, G. Herning

1.563 Structural Design Project II
Prereq: None
G (Spring)
3-0-9 units

Students work in teams to design a tall building, emphasizing the design of vertical load systems, lateral load systems, and floor systems. Uses studies of precedent buildings and metrics of structural performance including material efficiency and embodied carbon to evaluate multiple design concepts. Simplified calculation methods are validated with advanced numerical simulations. Formal presentations will be used to improve oral and visual communication.

J. Ochsendorf

1.564 Micromechanics and Durability of Solids
Prereq: 1.050, 1.57; or permission of instructor
Acad Year 2016-2017: G (Spring)
Acad Year 2017-2018: Not offered
3-0-9 units

Introduction to fracture mechanics, poromechanics and micromechanics using a unified mechanistic approach based on energy principles for modeling a large range of man-made and natural engineering material behavior. Energy release and fracture energy, stress intensity factors and toughness, saturated and partially saturated poromechanics of deformable porous materials, Darcy's law, linear micromechanics and application to porous materials, homogenization methods, chemomechanics of dissolution processes. In addition to assignments, emphasizes development of a consistent engineering science approach, culminating in a term paper.

F. J. Ulm

1.565 Mechanics of Materials: An Energy Approach
Prereq: 1.050 or permission of instructor
G (Fall)
Not offered regularly; consult department
3-2-7 units

An opportunity to update knowledge in continuum mechanics and constitutive behavior, and modeling of engineering materials based on thermodynamics of irreversible processes. Introduction to continuum mechanics and material modeling of engineering materials based on first energy principles: deformation and strain; momentum balance, stress, and stress states; elasticity and elasticity bounds; plasticity and yield design. Overarching theme is a unified mechanistic language using thermodynamics, which allows for understanding, modeling, and design of a broad range of engineering materials.

F. J. Ulm
1.571 Modeling and Analysis of Structures
Prereq: Permission of instructor
G (Spring)
3-0-9 units
Covers analytical and computer-based methods for the analysis of structural systems. Introduces strategies for the quantitative study of indeterminate and nonlinear structures. Topics provide insight into structural analysis software and the implementation of the finite element method. Emphasizes modeling complex structural behavior, such as elastic instability, local and global buckling, physical nonlinearity, geometric stiffness, and thermal expansion. Application examples cover a range of structural components and systems, with models and methods specific to the study of building frames, arches, shells, and cable-supported and tensile structures. Assignments provide experience with the construction of mathematical and finite element models, the derivation of closed-form solutions, and the effective use of structural analysis programs.
Staff

1.572 Structural Systems
Prereq: Permission of instructor
G (Spring)
3-0-6 units
Designed to complement general structural analysis classes. Provides an understanding of the full range of structures and structural forms, including how they are designed and built. Develops skills necessary for conceptual design work, such as how to visualize options and judge their relative advantages in a qualitative manner. Case studies demonstrate how to conceive a structural form and consider its various options, and to understand assembly and construction methods intrinsic to the real behavior of the final structure.
Staff

1.573[J] Structural Mechanics
Same subject as 2.080[J]
Prereq: 2.002
G (Fall)
4-0-8 units
See description under subject 2.080[J].
T. Wierzbicki, H. Schmidt

1.574[J] Analysis of Historic Structures
Same subject as 4.445[J]
Subject meets with 4.444
Prereq: None
G (Fall)
3-0-6 units
See description under subject 4.445[J].
J. Ochsendorf

1.575[J] Computational Structural Design and Optimization (New)
Same subject as 4.450[J]
Prereq: Permission of instructor
G (Fall)
Units arranged
See description under subject 4.450[J].
C. Mueller

1.581[J] Structural Dynamics and Vibrations
Same subject as 2.060[J], 16.221[J]
Subject meets with 1.058
Prereq: Permission of instructor
G (Fall)
3-1-8 units
Single- and multiple-degree-of-freedom vibration problems, using matrix formulation and normal mode superposition methods. Time and frequency domain solution techniques including convolution and Fourier transforms. Applications to vibration isolation, damping treatment, and dynamic absorbers. Analysis of continuous systems by exact and approximate methods. Applications to buildings, ships, aircraft and offshore structures. Vibration measurement and analysis techniques. Students should possess basic knowledge in structural mechanics and in linear algebra. Students taking graduate version complete additional assignments.
E. Kausel, J. K. Vandiver
1.582 Design of Steel Structures  
Prereq: Permission of instructor  
Acad Year 2016-2017: G (Fall)  
Acad Year 2017-2018: Not offered  
3-0-6 units  
Provides ability to design and assess steel structures. Steel structures are taught at three levels: the overall structural system (multi-story buildings, wide-span buildings, bridges, masts, and towers); the components of a structural system (floor systems, plate girders, frames, and beams); and the details of structural components (connection types, welding, and bolting). Each level includes a balance among theoretical analysis, design requirements, and construction/cost considerations. Existing structures are used as worked examples.  
*J. Ochsendorf, G. Herning*

1.589 Studies in Structural Design and Analysis  
Prereq: Permission of instructor  
G (Fall, Spring, Summer)  
Units arranged  
Can be repeated for credit.  
Individual study of advanced subjects under staff supervision. Content arranged to suit the particular requirements of the student and interested members of the staff.  
*Information: O. Buyukozturk*

1.597 Studies in Construction Materials  
Prereq: Permission of instructor  
G (Fall, Spring, Summer)  
Units arranged  
Can be repeated for credit.  
Advanced topics in construction materials selected by students for individual study with staff approval.  
*Information: O. Buyukozturk*

**Hydrodynamics and Coastal Engineering**

1.61 Transport Processes in the Environment  
Subject meets with 1.061  
Prereq: 1.060B  
G (Fall)  
3-1-8 units  
Introduces mass transport in environmental flows, with emphasis on river and lake systems. Covers derivation and solutions to the differential form of mass conservation equations. Topics include molecular and turbulent diffusion, boundary layers, dissolution, bed-water exchange, air-water exchange, and particle transport. Meets with 1.061A first half of term. Students taking graduate version complete additional assignments.  
*H. M. Nepf*

1.63[J] Advanced Fluid Dynamics  
Same subject as 2.26[J]  
Prereq: 18.085; 2.25 or permission of instructor.  
G (Spring)  
4-0-8 units  
See description under subject 2.26[J].  
*T. R. Akylas, G. H. McKinley, R. Stocker*

1.631[J] Fluid Dynamics and Disease  
Same subject as 2.250[J], HST.537[J]  
Prereq: None  
G (Spring)  
3-0-9 units  
Reviews theoretical notions in mathematical epidemiology and open problems in understanding and modeling disease onset and spread. Bridges the disease modeling efforts at the large-scale population-level and those at the micro-scale pathogen-level via the use of fluid dynamics. Covers topics such as interfacial flows, fluid fragmentation, multiphase flows, turbulent flows, and fluid-structure interaction. Intended for students with a strong quantitative background interested in learning about applications in health and epidemiology and for students with an epidemiology and health background interested in learning about fluid dynamics approaches relevant to disease transmission. In the spirit of the OneHealth Initiative, covers advanced topics on the health of human, animal, and plant populations.  
*L. Bourouiba*
1.64 Physical Limnology
Subject meets with 1.064
Prereq: 1.061
G (Spring)
Not offered regularly; consult department
3-0-9 units
Provides an introduction to physical processes occurring in lakes and shallow surface water systems with emphasis on mechanisms affecting fate and transport. Topics include internal waves, differential heating and cooling, boundary mixing, turbulent mixing, and influence of vegetation. Begins with a review of Navier-Stokes equation. Students taking graduate version complete additional assignments.
H. M. Nepf

1.66 Problems in Water Resources and Environmental Engineering
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.
Individual study in advanced topics as arranged between individual students and staff. Choice of subjects from theoretical, experimental, and practical phases of hydromechanics, hydraulic engineering, water resources, hydrology, and environmental engineering.
Staff

1.67 Sediment Transport and Coastal Processes
Prereq: 1.061
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
4-0-8 units
Staff

1.685[J] Nonlinear Dynamics and Waves
Same subject as 2.034[J], 18.377[J]
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
3-0-9 units
See description under subject 2.034[J].
T. R. Akylas

1.686[J] Nonlinear Dynamics and Turbulence
Same subject as 2.033[J], 18.358[J]
Subject meets with 1.068
Prereq: Permission of instructor
Acad Year 2016-2017: G (Spring)
Acad Year 2017-2018: Not offered
3-0-9 units
Reviews theoretical notions of nonlinear dynamics, instabilities, and waves with applications in fluid dynamics. Discusses hydrodynamic instabilities leading to flow destabilization and transition to turbulence. Focuses on physical turbulence and mixing from homogenous isotropic turbulence. Also covers topics such as rotating and stratified flows as they arise in the environment, wave-turbulence, and point source turbulent flows. Intended for students who have completed a fluid course. Students taking graduate version complete additional assignments.
L. Bourouiba

1.69 Introduction to Coastal Engineering
Prereq: 1.061
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
4-0-8 units
Basic dynamics of ocean surface waves; wave-driven, wind-driven, and tidal currents; boundary layers and sediment transport; and selected engineering applications. Formulation of the boundary-value problem for surface waves, linear plane-wave solution, shoaling, refraction, diffraction, statistical representation, and elements of nonlinearity. Depth-averaged formulation and selected solutions for sea level and currents driven by waves, winds, and tides. Elements of boundary layers, initial sediment motion, and bedload and suspended sediment transport. Alongshore sediment transport and shoreline change. Emphasizes basic principles, mathematical formulation and solution, and physical interpretation, with selected applications and exposure to current research.
J. Trowbridge
1.692[J] Ocean Wave Interaction with Ships and Offshore Energy Systems
Same subject as 2.24[J]
Prereq: 2.20, 18.085
Acad Year 2016-2017: G (Spring)
Acad Year 2017-2018: Not offered
4-0-8 units
See description under subject 2.24[J].
P. D. Sclavounos

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

Hydrology and Water Resource Systems

1.714 Surface Hydrology
Prereq: 1.070B[J] or permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3-0-9 units
Covers observations and theory of the physical processes involved in the hydrologic cycle. Processes considered are rainfall, infiltration, runoff generation, stream flow, evaporation, transpiration, and rainfall interception.
E. A. B. Eltahir

1.72 Groundwater Hydrology
Subject meets with 1.072
Prereq: 1.061
G (Fall)
3-1-8 units
Presents the fundamentals of subsurface flow and transport, emphasizing the role of groundwater in the hydrologic cycle, the relation of groundwater flow to geologic structure, and the management of contaminated groundwater. Topics include Darcy equation, flow nets, mass conservation, the aquifer flow equation, heterogeneity and anisotropy, storage properties, regional circulation, unsaturated flow, recharge, stream-aquifer interaction, well hydraulics, flow through fractured rock, numerical models, groundwater quality, contaminant transport processes, dispersion, decay, and adsorption. Includes laboratory and computer demonstrations. Students taking graduate version complete additional assignments.
C. Harvey

1.721 Advanced Subsurface Hydrology
Prereq: 1.72, 18.075, permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
3-0-9 units
C. Harvey

1.723 Computational Methods for Flow in Porous Media
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
3-0-9 units
R. Juanes
1.725 Chemicals in the Environment: Fate and Transport
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3-0-9 units

For Institute students in all departments interested in the behavior of chemicals in the environment. Subject covers the movement of chemicals through water, air, and soil, and also addresses their eventual fate. Physical transport, as well as chemical and biological sources and sinks, are discussed. Emphasis on anthropogenic chemicals, though in the context of pre-existing natural chemical cycles. Linkages to health effects, sources and control, and policy aspects. Core requirement for Environmental MEng program.

H. Hemond

1.731 Water Resource Systems
Subject meets with 1.075
Prereq: 1.070B[J] or permission of instructor
G (Fall)
3-0-9 units

Surveys optimization and simulation methods for management of water resources. Case studies illustrate linear, quadratic, nonlinear programming and real-time control. Applications include river basin planning, irrigation and agriculture, reservoir operations, capacity expansion, assimilation of remote sensing data, and sustainable resource development. Students taking graduate version complete additional assignments.

D. McLaughlin

1.74 Land, Water, Food, and Climate
Prereq: None
G (Spring)
3-0-3 units

Seminar examines food production in a changing world, with an emphasis on key scientific questions about the connections between natural resources, climate, and agriculture. Students read and discuss papers on a range of topics, including water and land resources, climate change, demography, agro-ecology, biotechnology, trade, and food security. Provides a broad and balanced perspective on one of the defining global issues of this century. Considers scientific controversies as well as areas of general agreement and examines practical solutions for addressing critical problems. Participants present reviews of selected papers and lead follow-up discussions. They also have a role in shaping subject content.

D. McLaughlin

Aquatic Sciences, Water Quality Control, and Environmental Management

1.75 Limnology and Wetland Ecology
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3-0-9 units

Examines the major physical, chemical, and biological features of lakes and wetlands: basin geology, water budget, heat balance, thermal stratification, lake circulation, energy flow, biological communities, and cycles of major elements. Explores methodologies of limnology, including field methods and use of models, applications of modern sensor technology to lake and wetland studies and current issues in lake and wetland management.

H. F. Hemond

1.76 Aquatic Chemistry
Prereq: Chemistry (GIR) or 5.60
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3-0-9 units

Quantitative treatment of chemical processes in aquatic systems such as lakes, oceans, rivers, estuaries, groundwaters, and wastewaters. A brief review of chemical thermodynamics is followed by discussion of acid-base, precipitation-dissolution, coordination, and reduction-oxidation reactions. Emphasis is on equilibrium calculations as a tool for understanding the variables that govern the chemical composition of aquatic systems and the fate of inorganic pollutants.

B. Kocar

1.77 Water Quality Control
Prereq: 1.060B
G (Spring)
3-0-9 units

Emphasizes mathematical models for predicting distribution and fate of effluents discharged into lakes, reservoirs, rivers, estuaries, and oceans. Focuses on formulation and structure of models as well as analytical and simple numerical solution techniques. Role of element cycles, such as oxygen, nitrogen, and phosphorus, as water quality indicators. Offshore outfalls and diffusion. Salinity intrusion in estuaries. Thermal stratification, eutrophication, and sedimentation processes in lakes and reservoirs.

E. E. Adams
1.78 Introduction to Soil Science (New)
Subject meets with 1.078
Prereq: None
G (Fall)
3-1-8 units

Presents the physical, chemical, biological and genetic properties of soils, their global distribution, and response to management. Emphasizes factors controlling soil development, plant productivity, and the fate, cycling and bioavailability of soil nutrients and pollutants. Introduces Earth's different soil types and their classification; links characteristics with contemporary and historic issues surrounding natural and managed soil systems. Topics include soil carbon cycling, water and fertilizer management, and challenges associated with soil salinity-sodicity, erosion, and pollution. Includes field trips to local sites to examine soil physical properties, classification, and function. Introductory biology and chemistry are recommended prerequisites. Students taking graduate version complete additional assignments.

B. Kocar

1.801[J] Environmental Law, Policy, and Economics: Pollution Prevention and Control
Same subject as 11.021[J], 17.393[J]
Subject meets with 1.811[J], 11.630[J], IDS.430[J]
Prereq: None
U (Fall)
3-0-9 units. HASS-S

Credit cannot also be received for 15.663

Introduction to important issues in contemporary environmental law, policy, and economics. Discusses the roles and interactions of Congress, federal agencies, state governments, and the courts in dealing with environmental problems. Topics include common law, administrative law, environmental impact assessments required by the National Environmental Policy Act, and legislation and court decisions dealing with air pollution, water pollution, the control of hazardous waste, pollution and accident prevention, the production and use of toxic chemicals, community right-to-know, and environmental justice. Explores the role of science and economics in legal decisions, and economic incentives as an alternative or supplement to regulation. Analyzes pollution as an economic problem and a failure of markets. Introduction to basic legal skills: how to read and understand cases, regulation, and statutes; how to discover the current state of the law in a specific area; and how to take action toward resolution of environmental problems. Students taking the graduate version are expected to explore the subject in greater depth.

N. Ashford, C. Caldart

1.802[J] Regulation of Chemicals, Radiation, and Biotechnology
Same subject as 11.022[J]
Subject meets with 1.812[J], 10.805[J], 11.631[J], IDS.431[J], IDS.436[J]
Prereq: 1.801[J] or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-9 units

Focuses on policy design and evaluation in the regulation of hazardous substances and processes. Includes risk assessment, industrial chemicals, pesticides, food contaminants, pharmaceuticals, radiation and radioactive wastes, product safety, workplace hazards, indoor air pollution, biotechnology, victims' compensation, and administrative law. Health and economic consequences of regulation, as well as its potential to spur technological change, are discussed for each regulatory regime. Students taking the graduate version are expected to explore the subject in greater depth.

N. Ashford, C. Caldart

1.811[J] Environmental Law, Policy, and Economics: Pollution Prevention and Control
Same subject as 11.630[J], IDS.430[J]
Subject meets with 1.801[J], 11.021[J], 17.393[J]
Prereq: Permission of instructor for undergraduates
G (Fall)
3-0-9 units
Credit cannot also be received for 15.663

Reviews and analyzes federal and state regulation of air and water pollution, hazardous wastes, and the production and use of toxic chemicals. Analyzes pollution as an economic problem and the failure of markets. Emphasizes use of legal mechanisms and alternative approaches (such as economic incentives and voluntary approaches) to control pollution and to encourage chemical accident and pollution prevention. Focuses on the major federal legislation, the underlying administrative system, and the common law in analyzing environmental policy, economic consequences, and the role of the courts. Discusses classical pollutants and toxic industrial chemicals, community right-to-know, and environmental justice. Also provides an introduction to basic legal skills. Students taking the graduate version are expected to explore the subject in greater depth.

N. Ashford, C. Caldart
1.812[J] Regulation of Chemicals, Radiation, and Biotechnology
Same subject as 11.631[J], IDS.431[J]
Subject meets with 1.802[J], 10.805[J], 11.022[J], IDS.436[J]
Prereq: 1.811[J] or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units
Focuses on policy design and evaluation in the regulation of hazardous substances and processes. Includes risk assessment, industrial chemicals, pesticides, food contaminants, pharmaceuticals, radiation and radioactive wastes, product safety, workplace hazards, indoor air pollution, biotechnology, victims’ compensation, and administrative law. Health and economic consequences of regulation, as well as its potential to spur technological change, are discussed for each regulator regime. Students taking the graduate version are expected to explore the subject in greater depth.

N. Ashford, C. Caldart

1.813[J] Technology, Globalization, and Sustainable Development
Same subject as 11.466[J], 15.657[J], IDS.437[J]
Prereq: Permission of instructor
G (Fall)
3-0-9 units
See description under subject IDS.437[J].

N. Ashford

1.818[J] Sustainable Energy
Same subject as 2.65[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
G (Fall)
3-1-8 units
See description under subject 22.811[J].

M. W. Golay

1.819[J] Design for Sustainability
Same subject as 4.447[J]
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
2-0-4 units
Presents thought processes and quantitative tools, including life-cycle assessment (LCA) and the LEED and ENVISION rating systems, applicable to integrated design of buildings and horizontal infrastructure with the goal of minimizing the waste of materials, energy, and water. Readings, lectures, site visits, and assignments encourage systematic thinking and interdisciplinary collaboration to make sustainable design a reality. Includes a team project of students' choice, such as a conceptual design of a sustainable new building, a "green" retrofit, or a comparative LCA.
J. Ochsendorf

1.83 Environmental Organic Chemistry
Subject meets with 1.83
Prereq: 5.60, 18.03
G (Fall)
4-0-8 units
Focuses on the processes affecting organic compounds in the environment. Uses physical chemical properties to predict chemical transfers between environmental compartments (air, water, sediments, and biota). Uses molecular structure-reactivity relationships to estimate chemical, photochemical, and biochemical transformation rates. Resulting process models are combined to predict environmental concentrations (and related biological exposures) of anthropogenic and natural organic compounds.
P. M. Gschwend

1.831 Environmental Organic Chemistry
Subject meets with 1.83
Prereq: 5.60, 18.03
G (Fall)
4-0-8 units
Focuses on the processes affecting organic compounds in the environment. Uses physical chemical properties to predict chemical transfers between environmental compartments (air, water, sediments, and biota). Uses molecular properties to estimate chemical, photochemical, and biochemical transformation rates. Resulting process models are combined to predict environmental concentrations (and related biological exposures) of anthropogenic and natural organic compounds.
P. M. Gschwend
1.84[J] Atmospheric Chemistry
Same subject as 12.817[J], 12.807[J]
Prereq: 5.60
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3-0-9 units
Provides a detailed overview of the chemical transformations that control the abundances of key trace species in the Earth's atmosphere. Emphasizes the effects of human activity on air quality and climate. Topics include photochemistry, kinetics, and thermodynamics important to the chemistry of the atmosphere; stratospheric ozone depletion; oxidation chemistry of the troposphere; photochemical smog; aerosol chemistry; and sources and sinks of greenhouse gases and other climate forcers.
J. H. Kroll

1.841[J] Atmospheric Composition in the Changing Earth System
Same subject as 12.817[J]
Prereq: 1.84[J]
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
3-0-9 units
Explores how atmospheric chemical composition both drives and responds to climate, with a particular focus on feedbacks via the biosphere. Topics include atmospheric nitrogen; DMS, sulfate, and CLAW; biogenic volatile organic compounds and secondary organic aerosol; wildfires and land use change; atmospheric methane and the oxidative capacity of the troposphere; and air quality and climate and geoengineering.
C. Heald

1.842[J] Aerosol and Cloud Microphysics and Chemistry
Same subject as 12.814[J]
Subject meets with 12.338
Prereq: Permission of instructor
G (Spring)
3-0-9 units
See description under subject 12.814[J].
D. Cziczo

1.851[J] Water, Sanitation, Hygiene and Environmental Sanitation (WASH-ENV) in Low- and Middle-income Countries
Same subject as 11.479[J]
Prereq: None
Units: G (Spring)
3-0-9 units
Addresses principles and practice of water, sanitation, hygiene and environmental sanitation (WASH-ENV) systems, infrastructure, engineering, and planning in low- and middle-income countries. Incorporates interdisciplinary technical, socio-cultural, public health, human rights, behavioral, and economic aspects into the design and implementation of interventions. Students develop skills to plan simple, yet reliable, WASH-ENV systems together with urban or rural communities that are compatible with local customs and available human and material resources.
Staff

1.86[J] Methods and Problems in Microbiology
Same subject as 7.492[J], 20.445[J]
Prereq: None
G (Fall)
3-0-9 units
See description under subject 7.492[J]. Preference to first-year Microbiology and Biology students.
M. Laub

1.87[J] Microbial Genetics and Evolution
Same subject as 7.493[J], 12.493[J], 20.446[J]
Prereq: 7.03, 7.05, or permission of instructor
G (Fall)
4-0-8 units
See description under subject 7.493[J].
A. D. Grossman, G. Fournier

1.871 Computational Ecology (New)
Prereq: None
G (Fall)
3-0-9 units
Using high-throughput genome sequencing data, covers how to reconstruct the short-term ecological and long-term evolutionary dynamics of biological communities and populations. Emphasizes computational tools central to modern microbial ecology. Topics include computational phylogenetics, population genomics, ecological metagenomics, and ecological interactions.
O. Cordero
1.88 Physical Ecology at the Microscale
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

Designed for students in fluid mechanics and engineering who want to explore applications of physics and fluids to biology and ecology, and for students in the biological sciences seeking to understand the physical constraints of life at the microscale. Topics include mass exchange and flow at the scale of microbes, motility and chemotaxis, encounter rates and predation, and small-scale turbulence. Emphasizes the application of physical and fluid dynamical principles to life at the microscale, in particular (but not limited to) aquatic systems.

Staff

1.89 Environmental Microbiology
Subject meets with 1.089
Prereq: Biology (GIR)
G (Spring)
3-0-9 units

Provides a general introduction to the diverse roles of microorganisms in natural and artificial environments. Topics include energetics, and growth; evolution and gene flow; population and community dynamics; water and soil microbiology; biogeochemical cycling; and microorganisms in biodeterioration and bioremediation. 7.014 recommended as prerequisite; students taking graduate version complete additional assignments. Meets with 1.089A first half of term.

M. Polz, O. Cordero

1.899 Career Reengineering Program and Professional Development Workshops
Prereq: Permission of instructor
G (Spring)
1-0-0 units

For students in the 10-month Career Reengineering Program sponsored by the School of Engineering. Limited to CRP fellows.

Staff

Special Studies

1.91 Modeling Community Dynamics (New)
Prereq: Calculus II (GIR), 18.06 or permission of instructor
G (Spring)
3-0-9 units

Fundamentals of quantitative ecology and their application towards understanding the dynamics and persistence of ecological communities-ensemble of multiple species populations. Focuses on modeling principles from single, pairs, to multiple species. Modeling covers phenomenological and mechanistic understanding through graphical, analytical, and numerical analysis. Topics include growth, different notions of stability, feasibility, exploitation and maximization of resources, pest outbreaks, perturbations, species coexistence, and experiment-to-modeling approaches among others. Concepts applicable to micro- and macro-communities.

S. Saavedra

1.95[J] Teaching College-Level Science and Engineering
Same subject as 5.95[J], 7.59[J], 8.395[J], 18.094[J]
Subject meets with 2.978
Prereq: None
G (Fall)
2-0-2 units

See description under subject 5.95[J].

J. Rankin

1.968 Graduate Studies in Civil and Environmental Engineering
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.

1.969 Graduate Studies in Civil and Environmental Engineering
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.

Individual study, research, or laboratory investigations at the graduate level under faculty supervision.

Consult Department Academic Programs Office
1.982 Research in Civil and Environmental Engineering
Prereq: None
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

For research assistants in the department, when assigned research is not used for thesis but is approved for academic credit. Credit for this subject may not be used for any degree granted by Course 1. Consult Department Academic Programs Office

1.984 Teaching Experience in Civil and Environmental Engineering
Prereq: Permission of instructor
G (Fall, Spring)
0-2-0 units

Provides classroom teaching experience under the supervision of faculty member(s). Students prepare instructional material, deliver lectures, grade assignments, and prepare a teaching portfolio to be submitted at the end of term. Concurrent enrollment in 1.95[J] strongly recommended. Enrollment limited by availability of suitable teaching assignments.
Information: Academic Program Office

1.999 Undergraduate Studies in Civil and Environmental Engineering
Prereq: None
U (Fall, Spring, Summer)
Units arranged
Can be repeated for credit.

Individual study, research, or laboratory investigations under faculty supervision.
Consult Department Academic Programs Office

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

See description under subject 2.EPE.
Staff

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

Program of research leading to the writing of an SM, MEng, CE, PhD, or ScD thesis; to be arranged by the student and an appropriate MIT faculty member.
Consult Department Academic Programs Office

1.THU Undergraduate Thesis
Prereq: Permission of instructor
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Program of research leading to the writing of an S.B. thesis; to be arranged by the student and an appropriate MIT faculty member. Intended for seniors. Student must submit an approved thesis proposal to the Academic Programs Office by the fifth week of the first term the student is registered for thesis.
Consult Department Academic Programs Office

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

1.URG Research in Civil and Environmental Engineering
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Individual research or laboratory study under faculty supervision. Also opportunities in ongoing research program.
Consult Department Academic Programs Office
1.582 Special Problems in Environmental Microbiology and Chemistry
Prereq: Permission of instructor
G (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Advanced study of topics not covered in the regular subject listings, particularly seminar, laboratory, and experimental subjects offered by permanent or visiting faculty. Addresses topics in environmental microbiology, ecological genomics, microbial evolution and population genetics, oceanography, biogeochemical processes, environmental organic chemistry and aquatic chemistry.
S. W. Chisholm, M. F. Polz, E. J. Alm, P. M. Gschwend, H. F. Hemond

1.5977 Special Graduate Subject in Civil and Environmental Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring)
Units arranged
Can be repeated for credit.

Graduate subjects taught experimentally; subjects offered by visiting faculty; and seminars on topics of current interest not included in the regular curriculum. 1.978 is taught P/D/F.
Consult Department Academic Programs Office

1.5978 Special Graduate Subject in Civil and Environmental Engineering
Prereq: Permission of Instructor
G (Fall, IAP, Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Graduate subjects taught experimentally; subjects offered by visiting faculty; and seminars on topics of current interest not included in the regular curriculum. 1.978 is taught P/D/F.
Staff

1.5979 Special Graduate Subject in Civil and Environmental Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring)
Units arranged
Can be repeated for credit.

Graduate subjects taught experimentally; subjects offered by visiting faculty; and seminars on topics of current interest not included in the regular curriculum. 1.978 is taught P/D/F.
Consult Department Academic Programs Office

1.5980 Special Graduate Subject in Civil and Environmental Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring)
Units arranged
Can be repeated for credit.

Graduate subjects taught experimentally; subjects offered by visiting faculty; and seminars on topics of current interest not included in the regular curriculum. 1.978 is taught P/D/F.
Staff

1.5981 Special Graduate Subject in Civil and Environmental Engineering
Prereq: Permission of Instructor
G (Fall, IAP, Spring, Summer; first half of term)
Units arranged

Graduate subjects taught experimentally; subjects offered by visiting faculty; and seminars on topics of current interest not included in the regular curriculum. 1.978 is taught P/D/F.
Staff

1.5982 Special Graduate Subject in Civil and Environmental Engineering
Prereq: Permission of Instructor
G (Fall, IAP, Spring, Summer; second half of term)
Units arranged

Graduate subjects taught experimentally; subjects offered by visiting faculty; and seminars on topics of current interest not included in the regular curriculum. 1.978 is taught P/D/F.
Staff

1.5991 Special Undergraduate Subject in Civil and Environmental Engineering
Prereq: Permission of instructor
U (Fall, IAP, Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Subjects taught experimentally; subjects offered by visiting faculty; and seminars on topics of current interest not included in the regular curriculum. 1.991 is taught P/D/F.
Consult Department Academic Programs Office

1.5992 Special Undergraduate Subject in Civil and Environmental Engineering
Prereq: Permission of instructor
U (Fall, IAP, Spring)
Units arranged
Can be repeated for credit.

Subjects taught experimentally; subjects offered by visiting faculty; and seminars on topics of current interest not included in the regular curriculum. 1.992 is taught P/D/F.
Consult Department Academic Programs Office
1.S993 Special Undergraduate Subject in Civil and Environmental Engineering
Prereq: Permission of instructor
U (Fall, IAP, Spring)
Units arranged
Can be repeated for credit.

Subjects taught experimentally; subjects offered by visiting faculty; and seminars on topics of current interest not included in the regular curriculum. 1.S991 is taught P/D/F.
Consult Department Academic Programs Office