**FUNDAMENTALS**

1.00 Introduction to Computers and Engineering Problem Solving
(Subject meets with 1.001, 1.002)
Prereq: Calculus I (GIR)
U (Spring)
5-1-6 REST

1.001 Introduction to Computers and Engineering Problem Solving
(Subject meets with 1.00, 1.002)
Prereq: Calculus I (GIR)
G (Spring)
5-1-3

1.002 Introduction to Computers and Engineering Problem Solving
(Subject meets with 1.00, 1.001)
Prereq: Calculus I (GIR)
G (Spring)
5-1-6

Presents the fundamentals of object-based software design and development, computational methods and sensing for engineering, and scientific and managerial applications. Covers design of Web-based software, graphical user interfaces, numerical methods, streams, threads, sensors, and data structures. Students use the JavaScript programming language to complete weekly software assignments. Laptop computers available on loan. Students taking graduate version 1.002 complete additional assignments.

J. R. Williams

1.000 Computer Programming for Scientific and Engineering Applications (New)
Prereq: None. Coreq: 18.03
U (Fall)
3-2-7 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

1.007 EES-Lab: Engineering for Environment and Sustainability
Prereq: None
U (Spring)
1-2-6

Provides a practical introduction to key topics, current research and state-of-the-art tools in engineering for sustainability. Addresses engineering problems associated with the built and natural environments, with a focus on design of novel solutions to grand challenges related to energy, the environment, and sustainable societal growth. Organized around three themes: sustainable cities, energy and climate, and air, water, and health. Each week involves a lab or field trip related to a specific topic; examples include assessing the viability of sequestration, monitoring urban air pollution, collecting and observing the microorganisms that drive oceans' vital cycles, measuring the energy efficiency of buildings, and taking a boat on the Charles River for water quality measurements. Culminates in a field trip to Cape Cod.

Staff

1.010 Uncertainty in Engineering
Prereq: Calculus II (GIR)
U (Fall)
3-2-7

Introduction to 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

1.011 Project Evaluation and Management
Prereq: None
U (Spring)
3-0-9

Introduction to engineering projects as complex sociotechnical systems. Studies economic, financial, social and environmental influences and multi-disciplinary approaches for their analysis, design, construction, and management. Applies techniques such as benefit-cost analysis and lifecycle costing to develop a better understanding of these relationships. Students work in teams on a term project studying a large-scale infrastructure project in depth. Instruction and practice in oral and written communication provided.

J. Sussman, R. J. Schuhmann

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

Synthesizes prior design education through a term-long design project, concurrent implementation project, lectures and related assignments. Students who have specialized in structural, geotechnical, engineering systems, and environmental areas form mixed teams to work on the projects. For the term-long project, which must be planned and designed for a specific location, students demonstrate creativity in applying theories and methodologies from their design and analysis subjects while considering the project’s technical, environmental and social feasibility. Parallel to the design project is a related project involving actual implementation and analysis. Lectures on a variety of related civil and environmental engineering concepts, and engineering practice and ethics, are also part of the subject. Instruction and practice in oral and written communication are an integral part of the multiple design stages.

C. Heald, J. Kroll
### 1.015 Design of Electromechanical Robotic Systems
(Same subject as 2.017J)
- **Prereq:** 2.003 or 2.03; **Coreq:** 2.005, 2.05 and 2.051, or 2.016; 2.671
- **U (Spring)**
- **3-3-6 1/2 Institute LAB**
- See description under subject 2.017J.
  - F. S. Hover, J. J. Leonard

### 1.016 Design for Complex Environmental Issues: Building Solutions and Communicating Ideas
- **Prereq:** 12.000
- **Acad Year 2014–2015:** Not offered
- **Acad Year 2015–2016:** **U (Spring)**
  - **3-1-5**

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 term and to work in labs across MIT. Limited to Terrascope students.
  - C. Harvey

### 1.018A Fundamentals of Ecology I (New)
(Same subject as 7.30AJ, 12.031AJ)
- **Prereq:** None
- **U (Fall; first half of term)**
  - **2-0-4**

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 and 1.018B counts as REST subject.
  - S. Chisholm, M. Follows

### 1.018B Fundamentals of Ecology II (New)
(Same subject as 7.30BJ, 12.031BJ)
- **Prereq:** 1.018A
- **U (Fall; second half of term)**
  - **2-0-4**

Advanced topics in Ecology. Population modeling, global carbon cycle, climate change, geotechnology, theories of resource competition and mutualism, allometric scaling, ecological genomics, niche theory, human population
  - S. Chisholm, 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 REST**

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
- **U (Fall)**
  - **4-0-8 REST**

See description under subject 3.021.
  - M. Buehler, M. Demkowicz

### 1.022 Urban Networks (New)
- **Prereq:** 1.00 or 1.000; 1.010
- **U (Spring; first half of term)**
  - **3-0-3**

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 Geomaterials and Geomechanics
(Subject meets with 1.361, 1.366)
- **Prereq:** 1.010, 1.011, 1.036
- **U (Fall)**
  - **3-0-9**

Presentation and application of principles of soil mechanics. Considers topics: the origin and nature of soils; soil classification; the effective stress principle; hydraulic conductivity and seepage; stress-strain-strength behavior of cohesionless and cohesive soils and application to lateral earth stresses, bearing capacity and slope stability; consolidation theory and settlement analyses; laboratory and field methods for evaluation of soil properties in design practice. Same lectures as 1.361.
  - J. Germaine

### 1.035 Mechanics of Structures and Soils
- **Prereq:** 1.035
- **U (Spring)**
  - **3-1-8**

  - J. Germaine, P. Ghisbain, A. Whittle

### 1.036 Structural and Geotechnical Engineering Design
- **Prereq:** 1.035
- **U (Spring)**
  - **3-1-8**

Basic philosophy of planning and design of structures. Loading conditions, design criteria and factors of safety. Application of principles of structural mechanics and soil mechanics in design. Structural system design concepts. Design of reinforced concrete structural elements using the ultimate strength design method. Load factor design of structural steel members and connections. Selection of soil parameters from laboratory and in situ tests. Stability and ground deformations in geotechnical design. Design with soil-structure interaction. Emphasis on problem-based learning through team design projects.
  - O. Buyukozturk, L. C. Jen

### 1.041 Transportation Systems Modeling
(Same subject as ESD.01J)
- **Prereq:** 1.00 or 1.000; 1.010
- **U (Spring)**
  - **3-1-8**

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,
queuing 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

1.044J Fundamentals of Energy in Buildings
(Same subject as 2.66J, 4.42J)
Prereq: Physics I (GIR), Calculus II (GIR)
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Fall)
3-2-7 REST
See description under subject 4.42J.

1.050 Solid Mechanics
Prereq: Physics I (GIR); Coreq: Calculus II (GIR)
U (Fall)
3-2-7 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

1.053J Dynamics and Control I
(Same subject as 2.003J)
Prereq: Physics I (GIR), 18.03, or permission of instructor; Coreq: 2.066 or 1.020
U (Fall, Spring)
4-1-7 REST
See description under subject 2.003J.

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
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

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

J. Ochsendorf

1.058 Structural Dynamics and Vibrations
(Subject meets with 1.581J, 2.060J, 16.221J)
Prereq: Permission of instructor
U (Fall)
3-1-8
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 (New)
Prereq: Permission of instructor or Coreq: 18.03 or 18.034; Physics II (GIR)
U (Fall; first half of term)
2-1-3

R. Stocker

1.060B Fluid Mechanics II (New)
Prereq: 1.060A
U (Spring; second half of term)
2-1-3

R. Stocker

1.061A Transport Processes in the Environment I (New)
Prereq: 1.060A
U (Fall; first half of term)
2-1-3
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 1.61 first half of term.

H. Nepf

1.061B Transport Processes in the Environment II (New)
Prereq: 1.061A
U (Fall; second half of term)
2-1-3
Continues mass transport in environmental flows, with emphasis on river and lake systems. Studies dispersion, boundary layers, bed-water exchange, air-water exchange, and particle transport. Meets with 1.61 second half of term.

H. Nepf

1.062J Nonlinear Dynamics: Continuum Systems (New)
(Same subject as 12.207J, 18.354J)
Prereq: 18.03 or 18.034; Physics II (GIR)
G (Spring)
Not offered regularly; consult department
3-0-9 H-LEVEL Grad Credit (H except 1, 18)
General mathematical principles of continuum systems. From microscopic to macroscopic descriptions in the form of linear or nonlinear (partial) differential equations. Exact solutions, dimensional analysis, calculus of variations and singular perturbation methods. Stability, waves and pattern formation in continuum systems. Subject matter illustrated using natural fluid and solid systems found, for example, in geophysics and biology.

J. Dunkel

1.064 Physical Limnology
(Subject meets with 1.64)
Prereq: 1.061B
U (Spring)
Not offered regularly; consult department
3-0-9
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. Nepf

1.070A Introduction to Hydrology and Water Resources (New)
(Same subject as 12.320A)
Prereq: 1.060A; Coreq: 1.061A, 1.106
U (Fall; first half of term)
2-0-4
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 Introduction to Hydrology Modeling (New)
(Same subject as 12.320B)
Prereq: 1.070A
U (Fall; second half of term)
2-0-4
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 Global Change Science
(Same subject as 12.300J)
Prereq: 18.03
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Fall)
3-0-9
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: 1.061B
U (Fall)
3-1-8
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 (New)
Prereq: 1.010
U (Spring; first half of term)
2-0-4
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. A. B. Eltahir

1.074 Multivariate Data Analysis (New)
Prereq: 1.010
U (Spring; second half of term)
2-0-4
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.

M. Ben-Akiva

1.080A Environmental Chemistry I (New)
Prereq: Chemistry (GIR)
U (Spring; first half of term)
2-0-4
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 (New)
Prereq: 1.080A
U (Spring; second half of term)
2-0-4
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 of concentrations as a function of space and time.

B. D. Kocar

1.081 Environmental Risks, Prevention, and Therapy
(Same subject as 20.104J)
Prereq: Calculus II (GIR), Biology (GIR), Chemistry (GIR)
U (Spring)
3-0-9
See description under subject 20.104J.

W. Thilly, R. McCunney

1.082 Ethics for Engineers
Engineering School-Wide Elective Subject
(Offered under: 1.082, 2.900, 10.01)
Prereq: None
U (Fall)
2-0-4
See description under subject 10.01.

D. Doneson, B. L. Trout

1.083A Environmental Health Engineering and Biology I (New)
Prereq: Biology (GIR), Chemistry (GIR), 1.061A
U (Spring; first half of term)
2-0-4
Considers human health issues associated with environmental engineering for air, land, and water. Topics include the fundamental and applied aspects of biological and microbial processes in natural and engineered systems, including microbial metabolisms, water quality, ecological assessment, and wastewater treatment.

J. Thompson

1.083B Environmental Health Engineering and Biology II (New)
Prereq: 1.083A
U (Spring; second half of term)
2-0-4
Covers the interaction between humans and chemicals in the environment, including toxicology, exposure pathways, and risk assessment; treatment technologies; and the basis for
environmental regulation of chemical exposure. Case studies illustrate concepts and issues.

J. Thompson

1.084J Systems Microbiology
(Same subject as 20.106J)
Prereq: Chemistry (GIR), Biology (GIR)
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Fall)
3-0-9
See description under subject 20.106J.

J. Runstadler

1.085J Air Pollution
(Same subject as 12.336J)
Prereq: 18.03
U (Fall)
3-0-9
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
(Same subject meets with 1.89)
Prereq: Biology (GIR)
U (Fall)
3-0-9
Provides a general introduction to the diverse roles of microorganisms in natural and artificial environments. Topics include cellular architecture, 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.

J. R. Thompson

1.091 Traveling Research Environmental Experience (TREX): Fieldwork (New)
Prereq: Permission of instructor
U (IAP)
3-0-3
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 environmental research projects. Location varies year-to-year, though recent projects have focused on the Big Island of Hawaii. Students interested in focusing more deeply on interpretation and communication of results should instead enroll in 1.092 (which continues into the spring). Meets with 1.092 during IAP. Limited to Course 1 students.

J. Kroll

1.092 Traveling Research Environmental Experience (TREX): Fieldwork, Analysis, and Communication
Prereq: Permission of instructor
U (IAP, Spring)
5-2-5
Introduction to environmental fieldwork and research, covering data collection and analysis, interpretation of results, and science communication. Students conduct fieldwork during IAP, focusing on one or more environmental research projects. Spring term activities involve 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 the research project(s), and write-ups of the research in manuscript form. Meets with 1.091 during IAP. Limited to Course 1 majors and minors.

J. Kroll

1.093 Introduction to Computer-Aided Design
Prereq: Permission of instructor
U (IAP)
2-0-2
Introduces concepts of computer-aided design (CAD) though the use of modeling software. Provides the basic skills applicable to various CAD programs. Students create 2-D wireframe geometry, 3-D solid models, and produce dimensioned drawings. Licensed software provided for class use. Limited to 20; preference to Course 1 students.

Staff

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

1.101 Introduction to Civil and Environmental Engineering Design I
Prereq: None
U (Fall)
0-3-3 1/2 Institute LAB
Project-oriented introduction to the principles and practice of civil and environmental engineering design. First half of the term, students work in teams to apply the design process to an open-ended design/planning problem involving civil and environmental engineering aspects. In the second half, teams design and build a working model researching, in detail, an aspect of the planning/design project. Each team then presents the model and the results to the class. Regular written and oral presentations. Students also start on their design portfolio. Enrollment limited; preference to Course 1 majors and minors.

H. H. Einstein

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 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.

H. F. Hemond

1.106 Environmental Fluid Transport Processes and Hydrology Laboratory
Prereq: None. Coreq: 1.061A, 1.070A
U (Fall)
0-4-2 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 and 1-E students.

H. Nepf
1.107 Environmental Chemistry and Biology Laboratory
Prereq: 1.018A or permission of instructor; Coreq: 1.080A
U (Spring)
0-4-2 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-E students.
*P. Gschwend, B. Kocar*

**ENGINEERING INFORMATION SYSTEMS AND COMPUTATION**

1.124J Software and Computation for Simulation
(Same subject as 2.091J, ESD.51J)
Prereq: 1.00 or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
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 searching 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*

1.125J Architecting and Engineering Software Systems
(Same subject as ESD.341J)
Prereq: 1.00, 1.124J, or permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
See description under subject ESD.341J.
*J. R. Williams, A. Sanchez*

1.126J Pattern Recognition and Analysis
(Same subject as MAS.622J)
Prereq: Permission of instructor
Acad Year 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
See description under subject MAS.622J.
*R. W. Picard*

1.128J Computational Geometry
(Same subject as 2.089J)
Prereq: Permission of instructor
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
See description under subject 2.089J.
*N. M. Patrikalakis, D. C. Gossard*

**ENGINEERING ANALYSIS METHODS**

1.133 MEng Concepts of Engineering Practice
Prereq: Permission of instructor
G (Fall)
3-0-6 H-LEVEL Grad Credit
Core requirement for the MEng program designed to teach students about the roles of today’s professional engineer and expose them to team-building skills through lectures, team workshops, and seminars. Topics include: written and oral communication, job placement skills, trends in the engineering and construction industry, risk analysis and risk management, managing public information, proposal preparation, project evaluation, project management, liability, professional ethics, and negotiation. Draws on relevant large-scale projects to illustrate each component of the subject. Grading is based on both individual and team exercises involving written and oral presentations. Limited to Course 1 MEng students.
*E. E. Adams*

1.138J Wave Propagation
(Same subject as 2.062J, 18.376J)
Prereq: 2.003, 18.075
G (Spring)
3-0-9 H-LEVEL Grad Credit
See description under subject 2.062J.
*T. R. Akylas, R. R. Rosales*

See also 1.351, 1.541, 1.56J, 1.63, 1.691.

**ENGINEERING SYSTEMS, ECONOMICS, AND OPTIMIZATION**

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

1.145J Engineering Economy Module
(Same subject as ESD.70J)
Prereq: None
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall; partial term)
1-0-2 [P/D/F]
See description under subject ESD.70J.
*R. de Neufville*

1.146 Engineering Systems Analysis for Design
Engineering School-Wide Elective Subject
(Offered under: 1.146, 16.861, ESD.71)
(Subject meets with ESD.710)
Prereq: 1.145 or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
See description under subject ESD.71.
*R. de Neufville*

See also 1.202J, 1.203J, 1.283J, 1.731. For management of engineering systems, see also 1.462J–1.472J.
TRANSPORTATION

1.200J Transportation Systems Analysis: Performance and Optimization
(Same subject as 11.544J, ESD.211J)
Prereq: 1.010, permission of instructor
G (Fall)
3-1-8 H-LEVEL Grad Credit

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.

M. Ben-Akiva

1.201J Transportation Systems Analysis: Demand and Economics
(Same subject as 11.545J, ESD.210J)
Prereq: Permission of instructor
G (Fall)
3-1-8 H-LEVEL Grad Credit

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.

A. R. Odoni, C. Osorio

1.202J Demand Modeling
(Same subject as ESD.212J)
Prereq: 1.201 or permission of instructor
G (Spring)
3-1-8 H-LEVEL Grad Credit

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.

M. Ben-Akiva

1.203J Logistical and Transportation Planning Methods
(Same subject as 6.281J, 15.073J, 16.76J, ESD.216J)
Prereq: 6.041
G (Fall)
3-0-9 H-LEVEL Grad Credit

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. R. Odoni, A. I. Barnett

1.204 Computer Modeling: From Human Mobility to Transportation Networks
Prereq: 1.001, 1.010; or permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

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
1.205J Advanced Demand Modeling
(Same subject as ESD.213J)
Prereq: 1.202 or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
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
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
Staff

1.208 Resilient Infrastructure Networks
Prereq: 1.151 or 6.041/6.431; 15.058 or 15.093
G (Fall)
3-0-9 H-LEVEL Grad Credit
Control algorithms and game-theoretic tools to enable resilient operation of large-scale infrastructure networks. Dynamical network flow models, stability analysis, robust predictive control, fault and attack diagnostic tools. Strategic network design, routing games, congestion pricing, demand response, and incentive regulation. Design of operations management strategies for different reliability and security scenarios.
Applications to transportation, logistics, electric-power, and water distribution networks.
S. Amin

1.231J Planning and Design of Airport Systems
(Same subject as 16.781J, ESD.224J)
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
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. Odoni

1.232J The Airline Industry
(Same subject as 15.054J, 16.71J, ESD.217J)
Prereq: None
G (Fall)
3-0-9
See description under subject 16.71J.

1.233J Air Transportation Operations Research
(Same subject as 16.763J)
Prereq: 16.71J, 6.431J, 15.093, or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
See description under subject 16.763J.
H. Balakrishnan, C. Barnhart, P. P. Belobaba

1.234J Airline Management
(Same subject as 16.75J)
Prereq: 16.71J
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
See description under subject 16.75J.
P. P. Belobaba

1.251J Comparative Land Use and Transportation Planning
(Same subject as 11.526J)
Prereq: Permission of Instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
See description under subject 11.526J.
C. Zegras

1.252J Urban Transportation Planning
(Same subject as 11.540J, ESD.225J)
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
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.
Staff

1.253J Transportation Policy, the Environment, and Livable Communities
(Same subject as 11.543J, ESD.222J)
(Same subject as 11.526J)
Prereq: Permission of Instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
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)
3-0-9
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

1.255 Transportation MEng Project
Prereq: None. Coreq: 1.201
G (Fall, IAP, Spring)
5-0-10 H-LEVEL Grad Credit
Students work on projects related to ongoing MIT research programs with agencies, industries and government, such as Transport for London, or related transportation projects in the Boston area. An in-depth planning and design study is carried out as a group effort. Students must register for 1.255 for the Fall term, IAP, and the Spring term. Preference to Course 1 MEng students.

Staff

1.258J Public Transportation Systems
(Same subject as 11.541J, ESD.226J)
Prereq: 1.201 or permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
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

1.260J Logistics Systems
(Same subject as 15.770J, ESD.260J)
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
See description under subject ESD.260J.

Y. Sheffi, C. Caplice

1.261J Case Studies in Logistics and Supply Chain Management
(Same subject as 15.771J, ESD.261J)
Prereq: Permission of instructor
G (Spring)
3-0-6 H-LEVEL Grad Credit
See description under subject ESD.261J.

J. Byrnes

1.262J Supply Chain Leadership
(Same subject as ESD.262J)
Prereq: ESD.260 or permission of instructor
G (IAP)
2-0-7
See description under subject ESD.262J.

B. Arntzen, C. Caplice

1.264J Database, Internet, and Systems Integration Technologies
(Same subject as ESD.264J)
Prereq: Permission of instructor
G (Fall)
5-0-7 H-LEVEL Grad Credit
Addresses information technology fundamentals, including project management and software processes, data modeling, UML, relational databases and SQL. Covers internet technologies, such as XML, web services, and service-oriented architectures. Provides an introduction to security and presents the fundamentals of telecommunications. Includes a project that involves requirements/design, data model, database implementation, website, security and data network. No prior programming experience required.

C. Cassa

1.265J Global Supply Chain Management
(Same subject as 2.965J, 15.765J, ESD.265J)
Prereq: 1.260, 1.261, 15.761, 15.778, or permission of instructor
G (Spring)
2-0-4 H-LEVEL Grad Credit
Focuses on the planning, processes, and activities of supply chain management for companies involved in international commerce. Students examine the end-to-end processes and operational challenges in managing global supply chains, such as the basics of global trade, international transportation, duty, taxes, trade finance and hedging, currency issues, outsourcing, cultural differences, risks and security, and green supply chain issues. Highly interactive format features student-led discussions, staged debates, and a mock trial. Includes assignments on case studies and sourcing analysis, as well as projects and a final exam.

B. Arntzen

1.27 Studies in Transportation
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Individual advanced study of a topic in transportation systems, selected with the approval of the instructor.

Staff

1.271J The Theory of Operations Management
(Same subject as 15.764J, ESD.274J)
Prereq: 15.081J or 6.251J, 6.436J; or permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
See description under subject 15.764J.


1.273J Supply Chain Planning
(Same subject as 15.762J, ESD.267J)
Prereq: 1.260J, 15.760, or 15.761
G (Spring)
2-0-4 H-LEVEL Grad Credit
See description under subject 15.762J.

Staff

1.274J Manufacturing System and Supply Chain Design
(Same subject as 15.763J, ESD.268J)
Prereq: 1.260J, 15.761, or 15.778
G (Spring)
2-0-4 H-LEVEL Grad Credit
See description under subject 15.763J.

S. C. Graves, D. Simchi-Levi

1.283J Urban and Regional Economics
(Same subject as 11.410J, 14.573J, ESD.191J)
(Subject meets with 14.51)
Prereq: 14.04, 14.32
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
See description under subject 14.573J.

Consult W. Wheaton
1.284J Analyzing and Accounting for Regional Economic Change
(Same subject as 11.481J, ESD.192J)
Prereq: 14.03, 14.04
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
See description under subject 11.481J.
K. R. Polenske

1.285J Regional Socioeconomic Impact Analyses and Modeling
(Same subject as 11.482J, ESD.193J)
Prereq: 11.481J or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
2-1-9 H-LEVEL Grad Credit
See description under subject 11.482J.
K. R. Polenske

1.286J Energy and Infrastructure Technologies
(Same subject as 11.477J)
(Subject meets with 11.165)
Prereq: 14.01 or permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
See description under subject 11.477J.
K. R. Polenske

GEOENVIRONMENTAL AND GEOTECHNICAL ENGINEERING

1.322 Soil Behavior
Prereq: 1.361
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
4-0-8 H-LEVEL Grad Credit
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
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
E. Kausel

1.34 Waste Containment and Remediation Technology
Prereq: 1.72 or permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
Hazardous waste site remediation and waste disposal facility design. Introduction to hazardous waste including definitions, US federal regulations, waste characteristics, environmental chemistry, hydrology, and contaminant transport. Characterization and remediation of contaminated sites, including preliminary site assessment, site investigation techniques, remediation technologies, risk assessment, and monitoring for soils, groundwater, and sediments. Design, construction, operation, and hydrology of waste disposal facilities.
Staff

1.351 Theoretical Soil Mechanics
Prereq: 1.361
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
A. J. Whittle

1.361 Advanced Soil Mechanics
(Subject meets with 1.032, 1.366)
Prereq: 1.036
G (Fall)
3-0-9 H-LEVEL Grad Credit
Consideration of the following fundamentals of soil mechanics: the nature of soil; the effective stress principle; hydraulic conductivity and seepage; stress-strain-strength behavior of cohesionless and cohesive soil; lateral earth stresses; bearing capacity and slope stability; consolidation theory; and settlement analyses. Core requirement for Geoenvironmental MEng program.
J. Germaine

1.364 Advanced Geotechnical Engineering
Prereq: None. Coreq: 1.361
G (Fall)
4-0-8 H-LEVEL Grad Credit
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 rafts) and deep (piles and caissons) foundations, excavation support systems, groundwater control, slope stability, soil improvement (compaction, soil reinforcement, etc.), and construction monitoring. Core requirement for Geotechnical MEng program.
A. Whittle

1.366 Geotechnical Engineering
(Subject meets with 1.032, 1.361)
Prereq: 1.035, 1.036
G (Fall)
3-0-6 H-LEVEL Grad Credit
Identification, presentation, and illustration of principles of soil mechanics. Considers the following topics: the nature of soil; the effective stress principle; hydraulic conductivity and seepage; stress-strain-strength behavior of soil; and lateral earth stresses. Applies principles to stability and deformation problems. Restricted to graduate students not specializing in Geotechnical Engineering. Same lectures as 1.361.
J. Germaine

1.37 Geotechnical Measurements and Exploration
Prereq: 1.035
G (Fall)
3-4-2 H-LEVEL Grad Credit
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 bound-
ay 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.

**J. Germaine**

**1.38 Engineering Geology**
Prereq: Permission of instructor
G (Fall)
3-1-8 H-LEVEL Grad Credit

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 sedimented and residual soils. Laboratory on basic geologic identification and mapping techniques. Extensive reading of case histories. Field trip.

*H. H. Einstein*

**1.381 Rock Mechanics**
Prereq: 1.38, 1.361
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-6 H-LEVEL Grad Credit

Introduces theoretical and experimental aspects of rock mechanics and on this basis prepares the student for rock engineering. Includes review of laboratory and field testing; empirical and analytical methods for describing strength, deformability, and permeability of intact rock and rock masses; fracture mechanics and mechanics of discontinua including flow through discontinuia; design and analysis of rock slopes and foundations on rock; and discussion of blasting design.

*H. H. Einstein*

**1.383 Underground Construction**
Prereq: 1.361, 1.38, or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-6 H-LEVEL Grad Credit

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.

*H. H. Einstein*

**1.39 Independent Study in Geotechnical Engineering**
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
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**

**1.462J Entrepreneurship in Construction and Real Estate Development**
(Same subject as 11.345J)
Prereq: Permission of Instructor
G (Fall; second half of term)
2-0-4 H-LEVEL Grad Credit

See description under subject 11.345J.

*J. F. Kennedy*

**1.463J Globalization and the Built Environment**
(Same subject as 11.342J, ESD.53J)
Prereq: Permission of instructor
G (Fall)
2-0-4 H-LEVEL Grad Credit

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*

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

See description under subject 11.344J.

*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 H-LEVEL Grad Credit

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 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit

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*

**1.561 Structural Mechanics in Nuclear Power Technology**
(Subject meets as 2.084J, 22.314J)
Prereq: 2.001 or permission of instructor
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit

See description under subject 22.314J.

*M. S. Kazimi*
1.561 Motion-Based Design
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
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. J. Connor, Jr.

1.562 High-Performance Structures MEng Project
Prereq: None. Coreq: 1.561
G (Fall, IAP, Spring)
5-0-10 H-LEVEL Grad Credit
Core requirement for the High Performance Structures MEng program. Focus on the conceptual design of complex structures and the use of advanced technologies to improve the performance of structural systems with respect to their durability, constructability, efficiency and sustainability. An in-depth design study is carried out as a group effort and provides the background for individual student theses. Students must register for 1.562 for the Fall term, IAP, and the Spring term. Limited to Course 1 MEng students.
P. Ghisbain

1.57 Mechanics of Materials: An Energy Approach
Prereq: 1.050 or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-2-7 H-LEVEL Grad Credit
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

1.570 Micromechanics and Durability of Solids
Prereq: 1.050, 1.57; or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
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

1.571 Modeling and Analysis of Structures
Prereq: Permission of Instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
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.
P. Ghisbain

1.572 Structural Systems
Prereq: Permission of instructor
G (Fall)
3-0-6 H-LEVEL Grad Credit
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

1.573J Structural Mechanics
(Same subject as 2.080J)
Prereq: 2.002
G (Fall)
4-0-8 H-LEVEL Grad Credit
See description under subject 2.080J.
T. Wierzbicki, J. J. Connor, Jr., H. Schmidt

1.581J Structural Dynamics and Vibrations
(Same subject as 2.060J, 16.221J)
Subject meets with 1.058
Prereq: Permission of instructor
G (Fall)
3-1-8 H-LEVEL Grad Credit
Single- and multiple-degree-of-freedom vibration problems, using matrix formulation and normal mode superposition methods. 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.
J. K. Vandiver

1.582 Design of Steel Structures
Prereq: Permission of instructor
G (Spring)
3-0-6 H-LEVEL Grad Credit
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.
Staff
HYDROLOGY AND WATER RESOURCE SYSTEMS

1.714 Surface Hydrology
Prereq: 1.070 or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit

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: 1.061B
G (Fall)
3-1-8 H-LEVEL Grad Credit

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, nonlinear aspects and wave breaking. Emphasizes physical interpretation of mathematical results and their engineering application. Storm surges, coastal circulation, and forecasting of wind-wave characteristics. Wind-wave statistics, wave forces on piles, and breakwater stability.

J. Trowbridge

1.589 Studies in Structural Design and Analysis
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
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 H-LEVEL Grad Credit
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
Prereq: 1.060B
G (Fall)
3-1-8

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 and 1.061B second half of term.

H. Nepf

1.63J Advanced Fluid Dynamics
(Subject as same as 2.26J)
Prereq: 18.085; 2.25 or permission of instructor.
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-8 H-LEVEL Grad Credit

See description under subject 2.26J.

T. R. Akylas, G. H. McKinley, R. Stocker

1.64 Physical Limnology
(Subject meets with 1.064)
Prereq: 1.061B
G (Spring)

Not offered regularly; consult department
3-0-9 H-LEVEL Grad Credit

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. Nepf

1.66 Problems in Water Resources and Environmental Engineering
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
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 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
4-0-8 H-LEVEL Grad Credit


Staff

1.685J Nonlinear Dynamics and Waves
(Same subject as 2.034J, 18.377J)
Prereq: Permission of instructor
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit

See description under subject 2.034J.

T. R. Akylas, R. R. Rosales

1.69 Introduction to Coastal Engineering
Prereq: 1.061
G (Fall)
4-0-8 H-LEVEL Grad Credit


J. Trowbridge

1.692J Ocean Wave Interaction with Ships and Offshore Energy Systems
(Same subject as 2.24J)
Prereq: 2.20, 18.085
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
4-0-8 H-LEVEL Grad Credit

See description under subject 2.24J.

P. D. Sclavounos

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

See description under subject 2.689J.

J. Preisig, WHOI Staff

C. Harvey

1.721 Advanced Subsurface Hydrology
Prereq: 1.72, 18.075, permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit


C. Harvey

1.723 Computational Methods for Flow in Porous Media
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit


R. Juanes

1.725J Chemicals in the Environment: Fate and Transport
(Same subject as ESD.151J)
Prereq: Permission of instructor
G (Fall)
3-0-9

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.

Staff

1.731 Water Resource Systems
Prereq: 1.070 or permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

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.

D. McLaughlin

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

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 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit

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 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit

Qualitative 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: 1.060
G (Spring)
3-0-9 H-LEVEL Grad Credit

Emphasis on 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. Core requirement for Environmental MEng program.

E. E. Adams

1.782 Environmental Engineering MEng Project
Prereq: Permission of instructor
G (Fall, IAP, Spring)
5-0-10 H-LEVEL Grad Credit

Core requirements for Environmental MEng program. Designed to teach about environmental engineering through the use of case studies, computer software tools, and seminars from industrial experts. Case studies provide basis for group project as well as individual thesis. Past case studies have included the MMR Superfund site on Cape Cod; restoration of the Florida Everglades; dredging of Boston Harbor; local watershed trading programs; appropriate wastewater treatment technology for Brazil; point-of-use water treatment for Nepal, Brownfields Develop-
ment in Providence, RI, and water resource planning for the island of Cyprus. Students must register for 1.782 for Fall term, IAP, and Spring term. Limited to Course 1 MEng students.

E. E. Adams

1.801J Environmental Law, Policy, and Economics: Pollution Prevention and Control
(Same subject as 11.021J, 17.393J)
(Subject meets with 1.811J, 11.630J, ESD.133J)
Prereq: None
U (Fall)
3-0-9 HASS-S
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

1.802J Regulation of Chemicals, Radiation, and Biotechnology
(Same subject as 11.022J)
(Subject meets with 1.812J, 10.805J, 11.631J, ESD.134J, ESD.136J)
Prereq: 1.801 or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-9
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

1.811J Environmental Law, Policy, and Economics: Pollution Prevention and Control
(Same subject as 11.630J, ESD.133J)
(Subject meets with 1.801J, 11.021J, 17.393J)
Prereq: Permission of instructor for undergraduates
G (Fall)
3-0-9 H-LEVEL Grad Credit
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

1.812J Regulation of Chemicals, Radiation, and Biotechnology
(Same subject as 11.631J, ESD.134J)
(Subject meets with 1.802J, 10.805J, 11.022J, ESD.136J)
Prereq: 1.811 or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 H-LEVEL Grad Credit
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

1.813J Technology, Globalization, and Sustainable Development
(Same subject as 11.466J, 15.657J, ESD.137J)
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
See description under subject ESD.137J.
N. Ashford

1.818J Sustainable Energy
(Same subject as 2.65J, 10.391J, 11.371J, 22.811J, ESD.166J)
(Subject meets with 2.65J, 10.291J, 22.081J)
Prereq: Permission of instructor
G (Fall)
3-1-8 H-LEVEL Grad Credit
See description under subject 22.811J.
M. W. Golay

1.819J Design for Sustainability
(Same subject as 4.447J)
Prereq: Permission of instructor
G (Fall)
2-0-4 H-LEVEL Grad Credit
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. Connor, J. Ochsendorf

1.83 Environmental Organic Chemistry
(Subject meets with 1.831)
Prereq: 5.60, 18.03
G (Fall)
4-0-8 H-LEVEL Grad Credit
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. Graduate students taking 1.83 for H-level credit
have additional reading and homework emphasizing structure-activity relationships.

P. M. Gschwend

1.831 Environmental Organic Chemistry
(Subject meets with 1.83)
Prereq: 5.60, 18.03
G (Fall)
4-0-8
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

1.84J Atmospheric Chemistry
(Same subject as 10.817J, 12.807J)
Prereq: 5.60
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
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

1.841J Atmospheric Composition in the Changing Earth System
(Same subject as 12.817J)
Prereq: 1.84
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
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

1.85 Water and Wastewater Treatment Engineering
Prereq: 1.061, 1.61, or 1.725
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9

Staff

1.851J Water, Sanitation, Hygiene and Environmental Sanitation (WASH-ENV) in Low- and Middle-Income Countries
(Same subject as 11.479J)
Prereq: None
G (Spring)
Units arranged
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

1.86J Methods and Problems in Microbiology
(Same subject as 7.492J, 20.445J)
Prereq: Permission of instructor or Coreq: 7.493
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
See description under subject 7.492J.

M. Polz

1.87J Microbial Genetics and Evolution
(Same subject as 7.493J, 20.446J)
Prereq: 7.03, 7.05, 7.28 or permission of instructor G (Fall)
4-0-8 H-LEVEL Grad Credit
See description under subject 7.493J.

A. D. Grossman, E. Alm

1.88 Physical Ecology at the Microscale
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
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.

R. Stocker

1.89 Environmental Microbiology
(Subject meets with 1.089)
Prereq: Biology (GIR)
G (Fall)
3-0-9 H-LEVEL Grad Credit
Provides a general introduction to the diverse roles of microorganisms in natural and artificial environments. Topics include cellular architecture, 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.

J. R. Thompson

1.899 Career Reengineering Program and Professional Development Workshops
Prereq: Permission of instructor
G (Spring)
1-0-0 [P/D/F]
For students in the 10-month Career Reengineering Program sponsored by the School of Engineering. Limited to CRP fellows.

Staff

SPECIAL STUDIES

1.95J Teaching College-Level Science and Engineering
(Same subject as 5.95J, 6.982J, 7.59J, 8.395J, 18.094J)
(Subject meets with 2.978)
Prereq: None
G (Fall)
2-0-2 [P/D/F]
See description under subject 5.95J.

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 H-LEVEL Grad Credit  
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

1.983 Teaching in Civil and Environmental Engineering  
Prereq: None  
G (fall, IAP, spring, summer)  
Units arranged [P/D/F]  
Can be repeated for credit  

For teaching assistants to recognize the educational value derived from satisfactory performance of assigned duties and for other qualified students interested in teaching as a career. Laboratory, tutorial, or classroom teaching under supervision of a faculty member. 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  

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 1.95J 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, 22.EPE)  
Prereq: 2.EPW or permission of instructor  
U (fall, spring)  
0-0-1 [P/D/F]  

See description under subject 2.EPE.  
Staff

1.EPW UPOP Engineering Practice Workshop  
Engineering School-Wide Elective Subject  
(Offered under: 1.EPW, 2.EPW, 3.EPW, 6.EPW, 10.EPW, 16.EPW, 20.EPW, 22.EPW)  
Prereq: None  
U (fall, IAP)  
1-0-0 [P/D/F]  

See description under subject 2.EPW.  
Staff

1.UR 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.URG Research in Civil and Environmental Engineering  
Prereq: None  
U (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.S82 Special Problems in Environmental Microbiology and Chemistry  
Prereq: Permission of instructor  
G (fall, spring)  
Units arranged [P/D/F] H-LEVEL Grad Credit  
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.  
### Bachelor of Science in Civil Engineering/Course 1-C

**General Institute Requirements (GIRs)**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total GIR Subjects Required for SB Degree</td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

**Communication Requirement**

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

**PLUS Departmental Program**

**Required Subjects**

<table>
<thead>
<tr>
<th>Subject Name</th>
<th>Units</th>
</tr>
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<tbody>
<tr>
<td>1.000 Computer Programming for Scientific and Engineering Applications, 12, REST; Calculus I (GIR)</td>
<td>159</td>
</tr>
<tr>
<td>1.010 Uncertainty in Engineering, 12, Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>1.013 Senior Civil and Environmental Engineering Design, 12, CI-M; permission of instructor</td>
<td></td>
</tr>
<tr>
<td>1.018A Fundamentals of Ecology I, 6*</td>
<td></td>
</tr>
<tr>
<td>1.018B Fundamentals of Ecology II, 6; 1.018A*</td>
<td></td>
</tr>
<tr>
<td>1.020 Principles of Energy and Water Sustainability, 12; Physics I (GIR), 18.03*</td>
<td></td>
</tr>
<tr>
<td>1.050 Solid Mechanics, 12, REST; Physics I (GIR), Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>1.060A Fluid Mechanics I, 6; 18.03*</td>
<td></td>
</tr>
<tr>
<td>1.060B Fluid Mechanics II, 6; 1.060A</td>
<td></td>
</tr>
<tr>
<td>18.04 Differential Equations, 12, REST; Calculus II (GIR)</td>
<td></td>
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</tbody>
</table>

**Civil Engineering**

<table>
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<tr>
<th>Subject Name</th>
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<tbody>
<tr>
<td>1.011 Project Evaluation and Management, 12, CI-M</td>
<td></td>
</tr>
<tr>
<td>1.035 Mechanics of Structures and Soils, 18; 1.050, 18.03*</td>
<td></td>
</tr>
<tr>
<td>1.036 Structural and Geotechnical Engineering Design, 12; 1.035</td>
<td></td>
</tr>
<tr>
<td>1.041 Transportation Systems Modeling, 12; 1.00*, 1.010*</td>
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**Laboratory**

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<tr>
<th>Subject Name</th>
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<tr>
<td>1.101 Introduction to Civil and Environmental Engineering Design I, 6, 1/2 LAB</td>
<td></td>
</tr>
<tr>
<td>1.102 Introduction to Civil and Environmental Engineering Design II, 6, 1/2 LAB; Physics II (GIR)*</td>
<td></td>
</tr>
</tbody>
</table>

**Restricted Electives**

One advanced subject from the following list (students may petition the department to substitute an upper-level subject in science or engineering):

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<td>1.015 Design of Electromechanical Robotic Systems, 12, 1/2 LAB; 2.005*; 2.671, 2.005*</td>
<td>12</td>
</tr>
<tr>
<td>1.032 Geomaterials and Geomechanics, 12; 1.010, 1.011, 1.036</td>
<td></td>
</tr>
<tr>
<td>1.054 Mechanics and Design of Concrete Structures, 12; 1.035</td>
<td></td>
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<tr>
<td>1.053 Transportation Policy, the Environment, and Livable Communities, 12; 1.011</td>
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**Departmental Program Units That Also Satisfy the GIRs**

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**Unrestricted Electives**

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<tbody>
<tr>
<td></td>
<td>48</td>
</tr>
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</table>

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

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</tr>
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<tbody>
<tr>
<td></td>
<td>183</td>
</tr>
</tbody>
</table>

**Notes**

* Alternate prerequisites and corequisites are listed in the subject description.

* The combination of 1.018A and 1.018B counts as a REST subject.

For an explanation of credit units, or hours, please refer to the online help of the MIT Subject Listing & Schedule, http://student.mit.edu/catalog/index.cgi.
# Bachelor of Science in Environmental Engineering Science/Course 1-E

## General Institute Requirements (GIRs)

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</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

## Communication Requirement

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

## PLUS Departmental Program

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

### Required Subjects

- **Core**
  - 1.018AJ Fundamentals of Ecology I, 6
  - 1.018BJ Fundamentals of Ecology II, 6; 1.018AJ
  - 1.020 Principles of Energy and Water Sustainability, 12; Physics I (GIR), 18.03*
  - 1.050 Solid Mechanics, 12, REST; Physics I (GIR), Calculus II (GIR)
  - 1.060A Fluid Mechanics I, 6; 18.03*
  - 1.060B Fluid Mechanics II, 6; 1.060A
  - 18.03 Differential Equations, 12, REST; Calculus II (GIR)
  - 1.013 Senior Civil and Environmental Engineering Design, 12, CI-M; permission of instructor
  - One of the following two subjects (3):
    - 1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; Calculus I (GIR)
    - 1.000 Computer Programming for Scientific and Engineering Applications, 12, REST; 18.03
  - 1.010 Uncertainty in Engineering, 12; Calculus II (GIR)

### Environmental Engineering Science

- 1.061A Transport Processes in the Environment I, 6; 1.060A
- 1.061B Transport Processes in the Environment II, 6; 1.061A
- 1.070A Introduction to Hydrology and Water Resources, 6; 1.060A, 1.061A, 1.106
- 1.070B Introduction to Hydrology Modeling, 6; 1.070A
- 1.080A Environmental Chemistry I, 6; Chemistry (GIR)
- 1.080B Environmental Chemistry II, 6; 1.080A
- 1.083A Environmental Health Engineering and Biology I, 6; 1.061A, Chemistry (GIR), Biology (GIR)
- 1.083B Environmental Health Engineering and Biology II, 6; 1.083A
- 1.106 Environmental Fluid Transport Processes and Hydrology Laboratory, 6, 1/2 LAB; 1.061A, 1.070A/
- 1.107 Environmental Chemistry and Biology Laboratory, 6, 1/2 LAB; 1.018A*, 1.080A

### Economics and Public Policy

One of the following three subjects:

- 1.801J Environmental Law, Policy, and Economics: Pollution Prevention & Control, 12; HASS-S
- 11.002J Making Public Policy, 12; HASS-S, CI-H
- 14.65 Principles of Microeconomics, 12; HASS-S

### Laboratory

- 1.101 Introduction to Civil and Environmental Engineering Design I, 6, 1/2 LAB
- 1.102 Introduction to Civil and Environmental Engineering Design II, 6, 1/2 LAB; Physics II (GIR)*

## Restricted Elective

One advanced subject from the following list (students may petition the department to substitute an upper-level subject in science or engineering):

- 1.064 Physical Limnology, 12; 1.061B
- 1.070J Global Change Science, 12; 18.03
- 1.072 Groundwater Hydrology, 12; 1.064B
- 1.085 Air Pollution, 12; 18.03
- 1.089 Environmental Microbiology, 12; Biology (GIR)
- 5.60 Thermodynamics and Kinetics, 12, REST; Chemistry (GIR), Calculus II (GIR)

## Departmental Program Units That Also Satisfy the GIRs

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(48)</td>
</tr>
</tbody>
</table>

## Unrestricted Electives

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
</tr>
</tbody>
</table>

## Total Units Beyond the GIRs Required for SB Degree

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

* Alternate prerequisites and corequisites are listed in the subject description.
1. Any of the subjects that fulfill the Institute Chemistry Requirement is satisfactory, though 5.111 or 5.112 is recommended.
2. The combination of 1.018AJ and 1.018BJ counts as a REST subject.
3. Students are encouraged to take both 1.00 and 1.010, in which case one may be counted as a restricted elective.

For an explanation of credit units, or hours, please refer to the online help of the MIT Subject Listing & Schedule, http://student.mit.edu/catalog/index.cgi.
Bachelor of Science in Engineering as Recommended by the Department of Civil and Environmental Engineering/Course 1-ENG

General Institute Requirements (GIRs) Subjects
Science Requirement 6
Humanities, Arts, and Social Sciences Requirement 8
Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 1.00, 1.000, and 18.03 in the Departmental Program] 2
Laboratory Requirement [can be satisfied from among 1.101, 1.102, 1.106, and 1.107 in the Departmental Program] 1
Total GIR Subjects Required for SB Degree 17

Communication Requirement(1)
The program includes a Communication Requirement of 4 subjects: 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and 2 subjects designated as Communication Intensive in the Major (CI-M).

PLUS Departmental Program Units

General Department Requirements (GDRs)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00 Introduction to Computers and Engineering Problem Solving, 12, REST; Calculus I (GIR) or 1.000 Computer Programming for Scientific and Engineering Applications, 12, REST; 18.03*</td>
<td>54</td>
</tr>
<tr>
<td>1.010 Uncertainty in Engineering, 12; Calculus II (GIR) 1.013 Senior Civil and Environmental Engineering Design, 12; CI-M; permission of instructor 1.073 Introduction to Environmental Data Analysis, 6; 1.010 or 1.074 Multivariate Data Analysis, 6; 1.010 18.03 Differential Equations, 12, REST; Calculus II (GIR)</td>
<td></td>
</tr>
</tbody>
</table>

Core Subjects

Students are required to formulate or select one area of core coursework. They can select from the following areas or create their own core from a combination of them with the approval of the CEE Program Officer.

Environment

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.018A Fundamentals of Ecology I, 6 1.060A Fluid Mechanics I, 6; 18.03* 1.061A Transport Processes in the Environment I, 6; 1.060A, 1.070A, 1.106 1.070A Introduction to Hydrology I, 6; 1.060A, 1.061A, 1.106 1.080A Environmental Chemistry I, 6; Chemistry (GIR) 1.083A Environmental Health Engineering and Biology, 6; Chemistry (GIR), Biology (GIR), 1.061A 1.092 Traveling Research Environmental Experience (TREX), 12, CI-M; permission of instructor 1.106 Environmental Fluid Transport Processes and Hydrology Laboratory, 6, LAB; 1.061A, 1.070A 1.107 Environmental Chemistry and Biology Laboratory, 6, LAB; 1.080A</td>
<td></td>
</tr>
</tbody>
</table>

Mechanics/Materials

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.035 Mechanics of Structures and Soils, 18; 1.050, 18.03 1.050 Solid Mechanics, 12; Physics I (GIR), Calculus II (GIR) 1.060A Fluid Mechanics I, 6; 18.03* 1.060B Fluid Mechanics II, 6; 1.060A 1.101 Introduction to Civil and Environmental Engineering Design I, 6, LAB 1.102 Introduction to Civil and Environmental Engineering Design II, 6, LAB; Physics II (GIR)*</td>
<td></td>
</tr>
</tbody>
</table>

Systems

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.011 Project Evaluation and Management, 12, CI-M 1.020 Principles of Energy and Water Sustainability, 12; Physics I (GIR), 18.03 1.022 Urban Networks, 6; 1.00*, 1.010 1.041J Transportation Systems Modeling, 12; 1.00*, 1.010 1.102 Introduction to Civil and Environmental Engineering Design I, 6, LAB 1.102 Introduction to Civil and Environmental Engineering Design II, 6, LAB; Physics II (GIR)*</td>
<td></td>
</tr>
</tbody>
</table>

Elective Subjects with Engineering Content

Students are required to take four Restricted Electives selected from subjects offered within or outside CEE to form a coherent program of study under supervision by CEE faculty.

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

Departmental Program Units That Also Satisfy the GIRs

(36)

Unrestricted Electives

48–54

Total Units Beyond the GIRs Required for SB Degree

180

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

To satisfy the CI-M component of the Communication Requirement, students must take two of the department’s CI-M subjects (1.011, 1.013, 1.092) 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. The outside CI-M must fit into the coherent program of electives approved by the student’s academic advisor.

For an explanation of credit units, or hours, please refer to the online help of the MIT Subject Listing & Schedule, http://student.mit.edu/catalog/index.cgi.