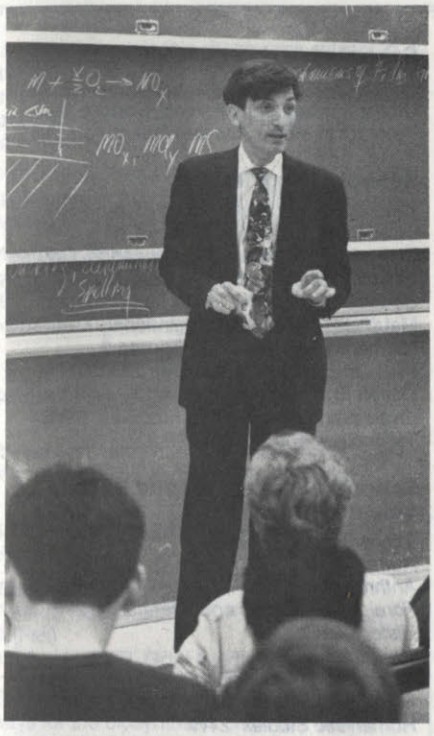

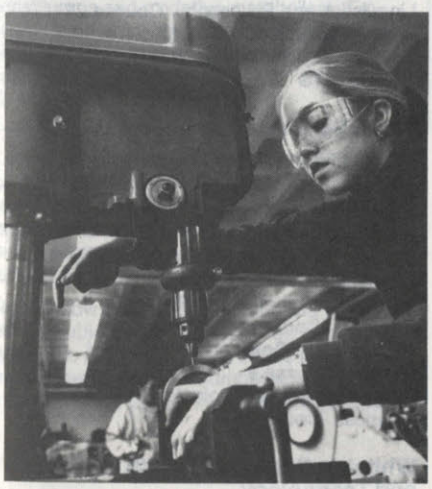

Refer to the introductory pages in this chapter for a list of departments and programs by Course and by School. Also, these pages explain how to decipher the abbreviations in the subject listings which follow.

Chapter VIII lists subjects department by department in numerical order by *Course*. Programs identified by letter abbreviations appear at the end of the numbered Courses.

Guide to Departments and Course Numbers

Chapter VIII of the catalogue contains descriptions of the subjects offered by MIT's departments and programs. The subjects are listed in numerical order by their Course numbers; letter-designated programs appear after the departmental listings.

In general, at the Institute, the word **Course** (capitalized) refers to an organized curriculum leading to a specified degree. The word **course** (lower-case) or **subject** refers to the individual class. Each Course is designated by a number or letter abbreviation; each individual subject offered by a Course is also numbered.

Departments/Programs by Course

Course 1 Civil and Environmental Engineering
Course 2 Mechanical Engineering
Course 3 Materials Science and Engineering
Course 4 Architecture
Course 5 Chemistry
Course 6 Electrical Engineering and Computer Science
Course 7 Biology
Course 8 Physics
Course 9 Brain and Cognitive Sciences
Course 10 Chemical Engineering
Course 11 Urban Studies and Planning
Course 12 Earth, Atmospheric, and Planetary Sciences
Course 13 Ocean Engineering
Course 14 Economics
Course 15 Management
Course 16 Aeronautics and Astronautics
Course 17 Political Science
Course 18 Mathematics
Course 20 Program in Applied Biological Sciences
Course 21 Humanities
- 21A *Anthropology*
- 21F *Foreign Languages and Literatures*
- 21H *History*
- 21L *Literature*
- 21M *Music and Theater Arts*
- 21W *Program in Writing and Humanistic Studies*

Course 22 Nuclear Engineering
Course 24 Linguistics and Philosophy

HST Harvard-MIT Division of Health Sciences and Technology
MAS Program in Media Arts and Sciences
SP Special Programs
STS Science, Technology, and Society
SWE Engineering School-Wide Electives
TOX Division of Toxicology
TPP Technology and Policy

ROTC
AS Aerospace Studies
MS Military Science
NS Naval Science

Departments/Programs by School

School of Architecture and Planning
Architecture **Course 4**
Urban Studies and Planning **Course 11**
Program in Media Arts and Sciences **MAS**

School of Engineering
Aeronautics and Astronautics **Course 16**
Chemical Engineering **Course 10**
Civil and Environmental Engineering **Course 1**
Electrical Engineering and Computer Science **Course 6**
Materials Science and Engineering **Course 3**
Mechanical Engineering **Course 2**
Nuclear Engineering **Course 22**
Ocean Engineering **Course 13**
Engineering School-Wide Electives **SWE**
Technology and Policy **TPP**

School of Humanities and Social Science
Economics **Course 14**
Humanities **Course 21**
Anthropology 21A
Foreign Languages and Literatures 21F
History 21H
Literature 21L
Music and Theater Arts 21M
Program in Writing and Humanistic Studies 21W
Linguistics and Philosophy **Course 24**
Political Science **Course 17**
Program in Science, Technology, and Society **STS**

Sloan School of Management
Management **Course 15**

School of Science
Biology **Course 7**
Brain and Cognitive Sciences **Course 9**
Chemistry **Course 5**
Earth, Atmospheric, and Planetary Sciences **Course 12**
Mathematics **Course 18**
Physics **Course 8**
Program in Applied Biological Sciences **Course 20**

Whitaker College of Health Sciences and Technology
Harvard-MIT Division of Health Sciences and Technology **HST**
Division of Toxicology **TOX**

Other Programs
Special Programs **SP**

ROTC
Aerospace Studies **AS**
Military Science **MS**
Naval Science **NS**

Guide to Subject Listings

The descriptions in this chapter are subject to change. The final list of subjects to be offered in 1996–97 is published with the class schedules booklet prior to the beginning of each term.

On the World Wide Web, see http://registrar.mit.edu/ for an integrated, searchable subject listing/schedule.

The following are examples of undergraduate and graduate subject listings. Each subject listing consists of three parts: the subject name, subject information, and subject description.

Subject Name

The subject name consists of its number and title, and appears above the first horizontal line.

5.77J Topics in Metabolic Biochemistry (New)

(Same subject as 7.75J)
Prereq.: 7.05 or 5.07
G (Fall)
4-0-8 H-LEVEL Grad Credit

Special topics include major metabolic pathways for the biosynthesis of certain cellular constituents and oxidative metabolism. Emphasis is on enzymology and methods used to understand metabolism and enzymatic processes.
G. M. Brown, J. Stubbe

J at the end of a subject number indicates that this subject is offered jointly by more than one department. The subject numbers of the other departments are indicated in the Subject Information section following the phrase **Same subject as**.

(New) below the subject number and title indicates a subject offering that is new to the catalogue. **(Revised Units)** or **(Revised Content)** below the subject number and title indicates a change from the previous catalogue.

Subject Information

Information about the subject appears below the first horizontal line.

18.014 Calculus with Theory

(18.012)
Prereq.: —
U (Fall)
5-0-7 CALC I
Credit cannot also be received for 18.01 or 18.011

Covers the same material as 18.01, but at a deeper and more rigorous level. Emphasizes careful reasoning and understanding of proofs. Assumes knowledge of elementary calculus. Topics: axioms for the real numbers; the Riemann integral; limits, theorems on continuous functions; derivatives of functions of one variable; the fundamental theorems of calculus; Taylor's theorem; infinite series, power series, rigorous treatment of the elementary functions.
J. R. Munkres

The former number of a **renumbered subject** is indicated in parentheses below the first horizontal line.

Same subject as appears in parentheses followed by the subject's other number(s) if the subject is joint or SWE. **Meets with** appears if the subject is taught together with one or more different-level subjects, or if part of the subject is taught in conjunction with another subject.

Prerequisite subjects, if any, are listed, or the prerequisite is described. Numbers in italics indicate **corequisites** — prerequisite subjects that may be taken simultaneously with the subject described. If there are no prerequisites or corequisites, a dash (—) appears. Prerequisites may be waived by the instructor in charge for particularly well-qualified students.

Year offered may state **Acad Year 1996–97: Not offered** or **Acad Year 1997–98: Not offered**. There is no comment if the subject is offered in both academic years 1996–97 and 1997–98.

Subject level and term follow. **U** is an undergraduate subject, and **G** is a subject primarily for graduate students. IAP is MIT's Independent Activities Period.

Credit units, which indicate a subject's time distribution, are represented by three numbers separated by dashes. The number of units assigned for recitation and lecture is first; for laboratory, design, or fieldwork second; and for preparation, third. Add all of the units together to obtain the total credit for a subject.

One unit represents approximately 14 hours of work. **Units arranged** indicates that units are specially arranged by the instructor.

Subjects fulfilling the General Institute Requirements, such as **BIOLOGY, PHYSICS, CALC, CHEMISTRY, REST** (Restricted Electives in Science and Technology, formerly SCI DIST), **Institute LAB**, or **HASS-D** (Humanities, Arts, and Social Sciences Distribution) are so designated to the right of the credit units.

HASS indicates subjects that can be used to satisfy the Humanities, Arts, and Social Sciences Requirement (other than HASS-D subjects).

HASS-D Language Option indicates language subjects which may be substituted for one HASS-D subject.

[P/D/F] appears to the right of the credit units if the subject is graded on a P, D, or F basis (where P means C or better performance).

H-LEVEL Grad Credit indicates an approved subject for higher graduate-level degree credit. In some cases, a message follows the designation indicating that the subject is H-level in certain departments.

Can be repeated for credit appears under the credit units if the subject can be taken more than once for academic credit.

Subject Description

The subject description appears below the second horizontal line.

21F.101 Chinese

(21.245)
Prereq.: —
U (Fall)
4-0-8 HASS

Introduction to spoken and written modern Chinese (Mandarin). Pronunciation, sentence structure, grammar, conversation, reading and writing. Lab work required. Enrollment limited to 20 students.
Y. Tai

Any subject open only to special groups is so noted at the end of its description. If the subject description does not appear, the number of the subject under which the description appears is given.

The **name of the instructor(s)** in charge as known at the time of publication is listed in italics, or the name of the departmental contact is listed in regular type.

Course 1

Civil and Environmental Engineering

For degree requirements, see listing in Chapter VII under the School of Engineering.

Fundamentals

1.00 Introduction to Computers and Engineering Problem Solving

(Subject meets with 1.001)
Prereq.: 18.01
U (Fall, Spring)
3-1-8 REST

Fundamental computational algorithms for engineering and scientific applications. Weekly programming problems cover numerical analysis, graphics, data structures, searching, sorting, matrix methods, and simulation. Emphasis on developing techniques for solving computational problems in engineering, science, management, and planning. Subject taught using the C++ programming language in the Fall term and the C programming language in the Spring term. Some programming background helpful, particularly for the Fall term.
Fall Term: *S. R. Lerman*
Spring Term: *E. A. Kausel*

1.001 Introduction to Computers and Engineering Problem Solving
(New)

(Subject meets with 1.00)
Prereq.: 18.01
G (Fall, Spring)
3-1-5

Meets with undergraduate subject 1.00. See description under 1.00.
Fall Term: *S. R. Lerman*
Spring Term: *E. A. Kausel*

1.03 Introduction to Probability and Statistics for Engineers

Prereq.: 18.01, 18.02
U (Fall)
3-2-7

Elements of probability and statistics with emphasis on engineering applications. Probability topics include univariate and multivariate distributions, estimation, and prediction; engineering reliability analysis; and Poisson and Markov processes. Statistics include classical and Bayesian methods of parameter estimation and hypothesis testing.
D. Veneziano

1.04 Solid Mechanics

Prereq.: 8.01, 18.01
U (Spring)
3-2-7 REST

Static equilibrium. Forces in trusses. Stress, strain, and Hooke's law; introduction to stress-strain behavior of construction materials. Torsion in members of circular cross-section. Stresses and deflections in beams. Stresses on inclined planes and the use of Mohr's circle for plane stress. Design project using Growltiger software package.
L. J. Gibson

1.05 Fluid Mechanics

Prereq.: 8.01, *18.03*
U (Spring)
3-2-7

Introduction to the mechanics of incompressible fluid flow. Fluid properties. Hydrostatics. Conservation of mass and momentum using differential and integral balances. The Bernoulli equation. Shear stresses and velocity profiles in laminar and turbulent flows. Dynamic similarity. First law of thermodynamics and the energy equation. Applications to steady flow in conduits and open channels, pumps, turbines, drag and lift on immersed objects.
O. S. Madsen

1.10J Environment and Technology

(Subject meets with 10.470J, 10.570J, TPP.52J)
Prereq.: —
U (Fall)
3-0-6

Introduction to environmental problems arising from commonplace technologies (e.g., plastics, electronics, automobiles). Considers the sustainability of resource use and the introduction of chemicals into the environment. Illustrates how to predict the fates of those chemicals in air-water-land-biota systems. Considers environmental and health consequences of products and the processes used for their manufacture. Discusses how we might respond to undesirable impacts, including product redesign and development of policies to achieve environmentally sensitive improvements. Meets with graduate subject 10.570J, but assignments differ.
P. Gschwend, J. Ehrenfeld, A. Sarofim

For additional undergraduate introductory subjects, see 1.30, 1.40, 1.50, 1.60, 1.70, 1.80.

Undergraduate Laboratory Subjects

1.102 Transportation Laboratory

Prereq.: —
U (Spring)
0-3-3 Institute LAB
Can be repeated for credit

Laboratory experience with the properties of transportation systems. Students formulate an experiment based upon readings and discussions of current transportation problems. Emphasis on formulation of hypotheses about properties and effects of different types of transportation systems; planning of experiments and data collection in the field to test these hypotheses, analysis of results, and development of recommendations for changes in transport systems plans and policies. Consult N. H. M. Wilson.

1.105 Structural Engineering Laboratory

Prereq.: —
U (Fall)
0-3-3 Institute LAB

Introduces students to properties of structural materials and behavior of simple structural elements and systems through a series of experiments. Several laboratory projects involve the student as both the designer and fabricator of a structure.
C. Leung

1.106 Fluid Mechanics Laboratory

Prereq.: —
U (Fall)
0-2-4 Institute LAB
Credit cannot also be received for 1.108

The measurement and analysis of physical parameters such as velocity, pressure, salinity, temperature, dissolved solids, etc., in closed conduits and natural water bodies. Application of these techniques in the context of six laboratory experiments. Certain experiments complement lectures in 1.05, but concurrent registration in 1.05 or previous fluid mechanics experience is not required. (Six additional units, satisfying the Institute Lab Requirement, may be obtained by registering for 1.108 rather than 1.106.)
E. E. Adams, H. M. Nepf

1.107 Aquatic Chemistry Laboratory

Prereq.: 5.11
U (Spring)
2-6-4 Institute LAB

Field sampling and laboratory analysis techniques for determining chemical (e.g., salinity, metals, O_2, nutrients, haloforms, petroleum hydrocarbons) and biological (e.g., chlorophyll, phytoplankton growth rates) parameters in aquatic samples. Both wet-chemical and instrumental (e.g., atomic absorption spectrometry and gas chromatography) methods. Field trips are taken to acquire "real world" samples for analysis and interpretation of the data in terms of water quality and the processes affecting it. An independently designed final project is required. Enrollment limited to 16 per section.
H. F. Hemond, S. Frankel

1.108 Environmental Fluid Mechanics Laboratory

Prereq.: —
U (Fall)
0-4-8 Institute LAB
Credit cannot also be received for 1.106

Extends the subject material of 1.106 by including additional laboratory experiments and one or more field experiments in topics of current interest in environmental fluid mechanics. Also includes end-of-term group design project.
E. E. Adams, H. M. Nepf

Engineering Information Systems and Computation

1.12 Computer Models of Physical and Engineering Systems

Prereq.: 18.03 or 18.034, 1.00
U (Spring)
3-1-8

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
F. Peña-Mora

1.120 Information Technology M.Eng. Project
(Revised Units)

Prereq.: 1.124J or knowledge of C++; limited to Course 1 M.Eng. students
G (Fall, IAP)
2-2-5 H-LEVEL Grad Credit

Core requirement for Information Technology M.Eng. program. Introduction to software design methodology focusing on the strategic and the analysis phases, which lead into the design phase. Students develop the feature set and functional specifications for a software product. Involves assessment of leading-edge products related to networks, CAE, GUIs, and groupware. Example projects might be a Web browser for engineering information (3D CAD etc.) or an information filter agent for networked databases. This is the Information Technology M.Eng. program project subject. Students must also register for 1.125 during the spring term.
J. R. Williams

1.124J Computer Aided Engineering I

(Same subject as 2.159J, 13.470J)
Prereq.: 1.00 and knowledge of C
G (Fall)
3-3-6 H-LEVEL Grad Credit

Foundations subject in modern software development techniques for numerical algorithms; the use of data structures and associated algorithms related to numerical analysis, geometric modeling, and visualization; basic problem-solving techniques using computational methods. Object-oriented software design (using C++); data structures sorting and searching algorithms; string processing, geometric, and graph algorithms; numerical and hierarchical analysis techniques; visualization techniques. Foundation for more in-depth exploration of computational geometry, geometric modeling, finite element methods, and network methods. Core requirement for Information Technology M.Eng. program.
J. R. Williams

1.125 Computer Aided Engineering II: Software Design and Development

Prereq.: 1.124J or Knowledge of C++
G (Spring)
3-3-6 H-LEVEL Grad Credit

Software design and development is concerned with long-term, large-scale programming projects. Subject introduces software design techniques through the development of a typical CAE package. Lectures cover object-oriented software design techniques including OMT, Rational Rose, Patterns, etc. and domain-specific concepts needed to implement the CAE package. Core requirement for Information Technology M.Eng. Program.
J. R. Williams

1.126J Pattern Recognition and Analysis

(Same subject as MAS.622J)
Prereq.: A working knowledge of probability theory and linear algebra
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject MAS.622J.
R. W. Picard, A. Bobick

1.127J Design and Implementation of Computer-Aided Engineering Systems

(Same subject as 2.157J, 13.471J)
Prereq.: Permission of instructor
G (Fall)
3-2-7 H-LEVEL Grad Credit

See description under subject 2.157J.
D. C. Gossard, N. M. Patrikalakis

1.128J Computational Geometry

(Same subject as 13.472J, 2.158J)
Prereq.: 13.471J/1.127J/2.157J or 6.837
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 13.472J.
N. M. Patrikalakis, D. C. Gossard

1.129 Information Content of the Design-Development Process

Prereq.: 1.12 and 1.432 or permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-9 H-LEVEL Grad Credit

Focuses on the identification, representation, and use of information developed, and explores the assumptions, concepts, and procedures which influence decision making during the design-development process. Examines how new information influences the generation of changes during the design-development process and how that information can be used for managing the changes. Considers the complexity of distributed decision making according to professional expertise, time difference, and geographical areas. Group projects emphasize the use of case studies and the development of information management systems. Mixed groups formed with information technology, engineering, and management students.
F. Peña-Mora

See also 1.204, 1.571, 1.70.

Engineering Analysis Methods

1.131 Mathematical Techniques and Engineering Applications

Prereq.: 18.03
G (Fall)
4-0-8 H-LEVEL Grad Credit

A utilitarian survey of elementary and intermediate analytical techniques, and their applications in physical systems important to engineering. Linear partial differential equations. Separation of variables. Green's functions. Fourier transforms. Bessel functions. Applications to seepage, traffic flows, statics and vibration of elastic structures, soil consolidation, and diffusion of heat or pollutants. Additional topics may include complex functions or perturbation techniques. Formulation of physical problems and analysis of mathematical solutions are emphasized.
C. C. Mei

1.133 M.Eng. Concepts of Engineering Practice
(Revised Units)

Prereq.: Limited to Course 1 M.Eng.students
G (Fall)
3-0-6 H-LEVEL Grad Credit

This core requirement for the M.Eng. program is 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 regulations, negotiations, risk analysis and risk management, information systems, ethics, managing public information, project evaluation, and project management. Draws on a relevant large-scale project to illustrate each component of the subject. Grading is based on both individual and team exercises along with oral and written presentations.
D. H. Marks

See also 1.351, 1.541, 1.56J, 1.571, 1.63, 1.691.

Engineering Systems, Economics, and Management

1.141J Strategic Analysis for Environmental Policy Planning, Design, and Implementation

(Same subject as 3.563J, 6.688J, 11.385J, 22.822J, TPP.121J)
Prereq.: 1.146 or 2.192 or 3.56 or 13.62 or 16.861 or TPP.21 or 11.200 or 11.205
G (Spring)
3-0-6 H-LEVEL Grad Credit

Gives participants practical understanding of the procedures for successfully designing complex technical systems that must perform well in a social context. Student teams work with computer-based models to examine the effect of alternative strategies; then define the tradeoffs between energy use, environmental quality, and costs, so as to develop a policy which is consistent with the social, economic, political and historical context of the region. The example treated is the proposed policy of requiring the introduction of personal electric cars in the Los Angeles region, as a means of reducing pollution.
D. H. Marks, R. de Neufville, J. Clark, R. Gakenheimer, M. W. Golay, D. Sadoway, R. D. Tabors

1.142 Civil Engineering Clinic

Prereq.: Permission of instructor
U (Spring)
1-10-1

Designed to expose students to real-world civil engineering projects and potential employment opportunities. A list of clinic subjects — encompassing structural, geotechnical, transportation, and construction engineering — has been developed in consultation with private and public "sponsors" (local consulting and contracting firms, government agencies, etc.). Students select a project and work jointly with an individual from the sponsoring firms and an MIT faculty member. Requires comprehensive written report and oral presentation.
L. J. Gibson

1.146 Engineering Systems Analysis

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

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
R. de Neufville, J. P. Clark, F. Field

1.147 Design for Product Realization

Prereq.: Permission of instructor
G (Spring)
3-0-6 H-LEVEL Grad Credit

Concerned with the process by which a concept for a product is formulated and transformed into an actual artifact. Focuses on the design and manufacture of large-scale complex engineered projects. Methodologies and tools of system engineering are introduced to develop models of the product and process, and analyze the relationships between critical design and production features. Topics include interaction matrices, program planning, systems modeling and analysis, control algorithms, axiomatic design principles, concurrent engineering processes, and computational design infrastructure. Core requirement for Information Technology M.Eng. program.
J. J. Connor, Jr.

1.148J Economics of Project Evaluation

(Same subject as 14.111J)
Prereq.: 14.03
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-6 H-LEVEL Grad Credit

See description under subject 14.111J. Consult P. Joskow.

See also 1.202, 1.203J, 1.207, 1.281, 1.283J, 1.70, 1.731. For management of engineering systems, see also 1.40–1.482.

Engineering Risk Assessment and Probabilistic Analysis

1.151 Probability and Statistics in Engineering

Prereq.: —
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-9 H-LEVEL Grad Credit

Quantitative analysis of uncertainty in planning, design, construction, and operation of engineered facilities. Fundamentals of probability, random processes, statistics, and decision analysis. Random variables and vectors and their transformations, second-moment analysis. Bayesian analysis and risk-based decision. Point and interval estimation, hypothesis testing, simple and multiple linear regression. Poisson and Markov processes.
D. Veneziano

1.155 Engineering Risk-Benefit Analysis

Prereq.: 18.02
G (Spring)
3-0-6 H-LEVEL Grad Credit

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
G. Apostolakis, A. W. Drake, A. R. Odoni

See also 1.203J, 1.711, 1.732.

Transportation

1.200 Methods for Transportation Systems Analysis

Prereq.: —
G (Fall)
3-1-8

Provides the methodological foundation necessary for the analytical study of the components of transportation systems and the relationships between them. Focuses on the use of linear equation systems, optimization techniques, and stochastic and statistical models. Develops the mathematical prerequisites for many advanced subjects in transportation.
C. Barnhart

1.201 Transportation Systems

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

Introduces the fundamental elements and issues shaping passenger and freight transportation systems. Discusses the role of transportation systems in society and measures of system effectiveness on many dimensions, including economic, environmental, and political. Covers deterministic and stochastic models of system performance and the determinants of transportation travel demand. Analyzes transportation networks, including prediction of costs and service quality. Considers the design of transportation services and facilities for various modes and intermodal operations. Case studies are used to show the application of methods to different types of transportation systems. Institutional and policy issues are addressed.
J. Sussman

1.202 Demand Modeling

Prereq.: Permission of instructor
G (Spring)
3-1-8 H-LEVEL Grad Credit

Analysis and forecasting of demand for facilities and services. Emphasis on collection and analysis of survey data. Review elements of probability, sampling, and statistical methods. Includes alternative sample designs and data collection methods, matrix-entry estimation methods, linear regression analysis, discrete choice methods, estimation and testing of disaggregate and aggregate models, aggregate forecasting methods and simulation. Illustrated with applications from the fields of transportation, housing, telecommunications, and marketing.
M. E. Ben-Akiva

1.203J Logistical and Transportation Planning Methods

(Same subject as 6.281J, 11.526J, 13.665J, 15.073J, 16.76J)
Prereq.: 6.431, 15.075
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, 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, 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, discussion of implementation difficulties.
A. I. Barnett, R. C. Larson, A. R. Odoni

1.204 Computer Algorithms in Transportation

Prereq.: 1.00 or 1.001 or permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Teaches techniques and tools for design, analysis, and implementation of efficient algorithms. An integrated view of algorithms, data structures, and computer architecture is emphasized. Algorithmic techniques studied include: greedy algorithms, divide-and-conquer, dynamic programming, probabilistic algorithms, network optimization based algorithms and graph traversal techniques. Advanced topics include: high-performance computing and real-time optimization.
I. Chabini

1.205 Advanced Demand Modeling

Prereq.: 1.202 or 14.388
G (Fall)
3-0-9 H-LEVEL Grad Credit

Theories and applications of behavior models. Includes: linear and nonlinear latent variable models, multidimensional probabilistic choice models, survey design, statistical estimation techniques with multiple data sources, model transferability, estimation and forecasting with very large choice sets, joint discrete and continuous models, dynamical models. Issues in model specification, including use of stated preference data, and analysis of complex choices. Term paper required.
M. E. Ben-Akiva

1.206 Optimization of Transportation Systems

Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-6 H-LEVEL Grad Credit

Explores a variety of optimization techniques for the solution of large-scale transportation problems. Models and solution methods, including decomposition and relaxation, are presented for a variety of problems faced by carriers and/or shippers. Students are required to complete a research project and to present their findings. Alternate years.
C. Barnhart

1.207 Models and Algorithms for Transportation Networks
(Revised Content)

Prereq.: 1.200 or permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

Formulation, analysis, and solution of network problems. Topics include: network equilibrium analysis; static system optimum traffic assignment; time-dependent approaches for dynamic systems; stochastic systems; simulation approaches; network control; implementation of various solution methods to solve large-scale applications.
I. Chabini

1.208J Transportation and Logistics Analysis

(Same subject as 15.770J)
Prereq.: Permission of instructor
G (Spring)
3-0-6 H-LEVEL Grad Credit

Introduction to inventory theory. Analysis of tradeoffs between transportation and inventory cost. Routing and scheduling with inventory considerations. Distribution network design and carrier network design. Optimization of carrier networks with emphasis on truck and rail networks. Integration of carrier and shipper perspective in system models. International logistics issues.
Y. Sheffi

1.209J Case Studies in Logistics and Supply Chain Management

(Same subject as 15.771J)
Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-6

A combination of lectures and cases covering the strategic, management, and operating issues in contemporary logistics and integrated supply chain management. Includes: logistics strategy; supply chain restructuring and change management; and distribution, customer service, and inventory policy.
Y. Sheffi

1.212 An Introduction to Intelligent Transportation Systems

Prereq.: Permission of Instructor
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-6 H-LEVEL Grad Credit

Basic elements of intelligent transportation systems. Technological, systems, and institutional aspects of ITS considered, including system architecture, congestion pricing, public/private partnerships, network models, ITS as industrial policy, implementation case studies. Term project required. Alternate years.
J. Sussman

1.231J Planning and Design of Airport Systems

(Same subject as 16.781J)
Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-6 H-LEVEL Grad Credit

Equal emphasis on current practice and advanced concepts. Airport location and planning with full consideration of economic, environmental, and other impacts. Demand prediction, determination of the capacity of the airfield, estimation of levels of congestion. Design of terminals. Role of airports in the aviation and transportation system. Airport access problems. Optimal configuration of air transport networks and implications for airport development. Economics of the airport. Financing and institutional aspects. Special attention to international practice and developments. Alternate years.
R. de Neufville, A. R. Odoni

1.233J Seminar in Air Transportation Analysis and Planning

(Same subject as 16.73J)
Prereq.: —
G (Fall)
1-0-5

See description under subject 16.73J.
A. R. Odoni, P. P. Belobaba

1.25J Technology, Policy, and Sustainability in the Middle East

(Same subject as 17.559J)
Prereq.: —
Acad Year 1996-97: U (Spring)
Acad Year 1997-98: **Not offered**
3-0-9

May *not* count toward HASS Requirement.
See description under subject 17.559J.
N. Choucri, F. Moavenzadeh

1.251J Transportation and Government — Public Policy and Politics

(Same subject as 11.379J)
Prereq.: —
G (Spring)
3-0-6

The reasons for government involvement in building transportation infrastructure, the organization and regulation of transportation services, and the safety and economic regulation of vehicles and the energy systems which fuel them. Reviews the historical, public policy, and political reasons for government involvement in transportation, and analyzes the current institutional mechanisms of government in air, water, rail, highway, auto, trucking, and transit systems. Issues include privatization, deregulation, federal program development, and intergovernmental conflicts.
F. Salvucci, R. Gakenheimer

1.252J Urban Transportation Planning

(Same subject as 11.380J)
Prereq.: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 11.380J.
R. A. Gakenheimer, F. Salvucci, T. Humphrey

1.254J Infrastructure in Developing Countries

(Subject meets with 11.469J, 11.104)
Prereq.: —
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 11.469J.
R. A. Gakenheimer

1.255J Political Economy and Technology in the Middle East

(Same subject as 17.558J, 21H.977J)
Prereq.: —
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

See description under subject 17.558J.
N. Choucri, F. Moavenzadeh, P. S. Khoury, R. Gakenheimer

1.256J Technology, Policy, and Sustainability in the Middle East

(Same subject as 17.560J)
Prereq.: —
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

See description under subject 17.560J.
N. Choucri, F. Moavenzadeh, R. Gakenheimer

1.258J Public Transportation Service and Operations Planning

(Same subject as 11.381J)
Prereq.: 1.201 or permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Evolution and role of urban public transportation modes, systems, and services, including bus and rail. Description of technological characteristics and their impacts on capacity, service quality, and cost. Current practice and new methods for performance monitoring, route design, vehicle and crew scheduling. Effect of pricing policy and service quality on ridership. Methods for estimating costs associated with proposed service changes.
N. H. M. Wilson

1.259J Transit Management

(Same subject as 11.382J)
Prereq.: 1.258J or permission of instructor
G (Fall)
3-0-6 H-LEVEL Grad Credit

Management methods of relevance to public transportation systems. Topics: strategic planning management; labor relations; maintenance planning and administration; financial planning; marketing; and management information and decision support systems. Shows how these general management tasks are dealt with in the transit industry and presents alternative strategies. Identifies alternative arrangements for service provision, including different ways of involving the private sector in public transportation.
N. H. M. Wilson, F. Salvucci

1.27 Studies in Transportation Engineering

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.
Information: N. H. M. Wilson.

1.271 Research Seminar in Transportation

Prereq.: Permission of instructor
G (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit

Discussion of current research at various stages of development, including problem definition, literature review, methodology, and evaluation of results. Intended for advanced doctoral students who have passed the general examination.
N. H. M. Wilson

1.281 Transportation Economics

Prereq.: 14.01
G (Spring)
3-0-6 H-LEVEL Grad Credit

Introduction to the economic analysis of transportation markets: urban and intercity, passenger and freight, national and international. Utility theory and its application to transport demand. Production theory and the analysis of transport costs. Market structures and transport pricing. Externalities. Public goods. The role of government in regulating transport and providing infrastructure.
Information: N. H. M. Wilson.

1.283J The Economics of Cities and Regions

(Same subject as 14.573J, 11.410J)
Prereq.: 14.03 or 14.04
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 14.573J.
W. Wheaton

1.284J Regional Economic Theories, Accounts, and Techniques

(Same subject as 11.481J)
Prereq.: 14.03, 14.04
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)
Prereq.: 11.481J or permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 11.482J.
K. R. Polenske

1.286 Freight Transportation Management

Prereq.: 1.201, 1.03
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Methods for analysis of freight systems, with emphasis on rail and motor carrier operations and management of carrier assets. Study of competitive transportation companies and the environment in which they operate. Market issues, organizational structure, information systems, and decisionmaking processes for fleet management, facility operations, maintenance, and operations/service planning. Case studies illustrate effects of regulation, technology, labor relations, and competition on carrier strategies. Alternate years.
C. D. Martland

Geoenvironmental and Geotechnical Engineering

1.30 Introduction to Geotechnical Engineering

Prereq.: 1.04
U (Fall)
3-2-7

Fundamentals of soil mechanics taught in context of three to four design exercises. Phase relationships; geostatic stresses; friction angles; Rankine and Coulomb earth pressures; effective stress; Darcy's law; heads; seepage force; flow nets; compression and swell of clays; consolidation and settlement; drained and undrained strength of simple clay; effective and total stress paths. Design exercises such as retaining walls with and without seepage, controlling settlements, and safe construction of embankments.
P. J. Culligan-Hensley

1.32 Introduction to Engineering Geology

Prereq.: —
U (Spring)
3-3-6 REST

Basic principles of physical geology, emphasizing topics pertinent to environmental and civil engineering. Identification of minerals; igneous, metamorphic, and sedimentary rocks. Alluvial, glacial, eolian, lacustrine, marine, and colluvial sediments. Weathering. Faults and fractures. Air photos and geologic maps. Field trips. Term paper; can be used for Phase 2 of the Writing Requirement.
H. H. Einstein

1.322 Soil Behavior

Prereq.: 1.361
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-1-8 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; engineering properties of compacted soils. Some knowledge of field and laboratory testing assumed; 1.37 desirable. Alternate years.
C. C. Ladd

1.331 Soil Dynamics

Prereq.: 1.361
G (Spring)
3-0-6 H-LEVEL Grad Credit

Stress-strain behavior during transient and repeated loadings, relation to wave velocity. Strength degradation and liquefaction. Analysis of foundations subjected to dynamic loadings; effect of soils upon seismic motions; earth dams and retaining walls during earthquakes; other selected applications. Alternate years.
Staff

1.34 Waste Containment and Remediation Technology

Prereq.: 1.30, permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Focuses on the geotechnical aspects of hazardous waste management, with specific emphasis on the design of land-based waste containment structures and hazardous waste remediation. Introduction to hazardous waste; definition of hazardous waste, regulatory requirements, waste characteristics, geochemistry, and contaminant transport. The design and operation of waste containment structures; landfills, impoundments, and mine-waste disposal. The characterization and remediation of contaminated sites; the superfund law, preliminary site assessment, site investigation techniques, and remediation technologies. Monitoring requirements.
P. J. Culligan-Hensley

1.351 Theoretical Soil Mechanics

Prereq.: 1.361
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Presentation of fundamental theories in soil mechanics: field equations of linear elasticity, solutions of boundary value problems. Introduction to finite element method. Steady and transient flow in porous media; applications in confined and unconfined seepage, one dimensional consolidation. Introduction to poro-elasticity. Yielding and failure of soils, plasticity theory and limit analyses; with examples for bearing capacity and slope stability. Cam Clay models and critical state theory of soil behavior.
A. J. Whittle

1.361 Advanced Soil Mechanics

Prereq.: 1.30
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; permeability and seepage; stress-strain-strength behavior of cohesionless and cohesive soil; lateral earth stresses; bearing capacity and slope stability; consolidation theory; settlement analyses. Core requirement for Geoenvironmental M.Eng. program.
C. C. Ladd

1.364 Advanced Geotechnical Engineering

Prereq.: 1.30, *1.361*
G (Fall)
3-0-9 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 raftings) 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 Geoenvironmental M.Eng. program.
A. J. Whittle

1.366 Geotechnical Engineering

Prereq.: 1.30
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; permeability and seepage; stress-strain-strength behavior of soil; lateral earth stresses. Applies principles to stability and deformation problems. Restricted to graduate students not specializing in Geotechnical Engineering. Same lectures as for 1.361.
C. C. Ladd

1.37 Geotechnical Measurements and Exploration

Prereq.: 1.30
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 boundary conditions. Exposure to error estimation, research devices, geotechnical field exploration, and *in situ* testing. Experiments include data analysis, evaluation, and presentation.
J. T. Germaine

1.38 Engineering Geology

Prereq.: 1.30, 1.32, or permission of instructor
G (Fall)
3-1-8 H-LEVEL Grad Credit

Effect of geologic features and processes on constructed facilities; interaction between man-made structures and human activities in general, and the geologic environment. 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. Occasional field trips.
H. H. Einstein

1.381 Rock Mechanics

Prereq.: 1.38, 1.361
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **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 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 discontinua; design and analysis of rock slopes and foundations on rock; discussion of blasting design. Alternate years.
H. H. Einstein

1.383 Underground Construction

Prereq.: 1.361, 1.38, or permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-6 H-LEVEL Grad Credit

Familiarization with the most important aspects of planning, design, and construction of underground openings in soft ground and rock. Detailed engineering analysis and design. Major aspects of construction techniques and construction planning. General planning and economic problems. Major design project. Alternate years.
H. H. Einstein

1.39 Studies 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 special topics.
Information: C. C. Ladd.

Construction Engineering and Management

1.40 Project Management

Prereq.: —
U (Fall)
3-0-9

Overview of construction industry, its organizations and interactions. Project and construction management methodologies presented for project and company planning, control, and decision-making. Includes scheduling, estimating, resource planning, organization structuring used throughout all phases of expected life of facility.
E. S. Slaughter

1.42J Fundamentals of Energy in Buildings

(Same subject as 4.42J, 2.45J)
Prereq.: 8.02, 18.02
U (Fall)
3-0-9 REST

See description under subject 4.42J.
L. R. Glicksman

1.420 Innovation in Construction
(New)

Prereq.: Permission of instructor
G (Spring)
3-0-6 H-LEVEL Grad Credit

Examines the current rate of innovation in the construction industry. Constant technological advances in materials, equipment, components, and methods are changing the nature of construction and the completed facilities. Explores these innovations and their effects on the building process. Considers application of general innovation theories to the construction industry. Identifies probable sources of construction innovation, such as suppliers, manufacturers, builders, and occupants. Regional differences in design requirements, means and methods, usage patterns also influence innovation development and use.
E. S. Slaughter

1.431 Structuring Construction Industry Organizations

Prereq.: —
G (Fall)
3-0-6 H-LEVEL Grad Credit

Examination, from a socio-technical perspective, of the organizations and organizational processes underlying the development, construction, and operation of the buildings. Studies the structure and functioning of firms, sub-units of firms, and conglomerations of firms with regard to the influence of a wide range of factors including strategy, human and other resources, and role in the project development process. Frameworks for observation, description, analysis, and design of individual enterprises presented and applied to real-world situations.
H. G. Irwig

1.432J Project Control
(Revised Content)

(Same subject as 13.615J)
Prereq.: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

Concepts, techniques, and information systems for planning, control, and management of large-scale engineering projects. Performance and control using estimating, scheduling, and financial data. Network-based planning and time control including CPM, PERT, and resource constrained schedule. Integration of cost and time control. Integration of project control with strategic plan and information systems. Examines how new information can be used for managing change. Considers the complexity of distributed decision making through workflow management. Covers the use of various commercial software.
F. Peña-Mora

1.44 Law and the Construction Industry

Prereq.: —
G (Fall)
2-0-7 H-LEVEL Grad Credit

Practical focus on key legal principles applicable to construction. Provides sufficient understanding to manage legal aspects, instead of being managed by them. Contractual relationships, contract performance, avoiding/resolving disputes, designing procurement systems, and legal aspects of contract strategies. Case study applications. Topics include forms of organization, changes, differing site conditions, designer liability, risk management, public construction, surety bonds, liens, E&O insurance, site safety, arbitration, ADR, partnering. Invited industry speakers, in-class arbitration.
J. B. Miller

1.441 Public Infrastructure Development Systems

(New)

Prereq.: 1.44 or permission of instructor
G (Spring)
3-0-6 H-LEVEL Grad Credit

Examination of new procurement and project management strategies based on financeable advances in technology from the private sector. Design of project delivery systems to create and encourage viable projects, new technology, private sector capital investment, competition, and best value. Systematic analysis for aligning technology, revenue, and financing opportunities with public infrastructure funding and needs. Case study development for air traffic control, waste water treatment, automatic toll collection, and multimodal port development. Invited industry speakers.
J. B. Miller

1.45 Construction Finance

Prereq.: —
G (Fall)
3-0-6 H-LEVEL Grad Credit

Examination of financing methods and structure, project financial evaluation, and financial management in the domestic and international construction industry. Analytical concepts and methodologies from modern finance theory and practice presented in lecture/discussions and applied to case analyses including problems in cash flow analysis, corporate financial structure, project finance, and foreign exchange exposure. Innovative financial securities, such as options, and methods such as privatization and sale-leaseback are examined. Prior subjects in microeconomics, accounting, and/or corporate finance desirable but not required.
M. V. Samii

1.46 Strategic Management in the Design and Construction Value Chain

Prereq.: Permission of instructor
G (Spring)
2-0-7 H-LEVEL Grad Credit

Examines the fundamental concepts of strategic planning and management in the context of the engineering and construction industry. Discusses the basic business relationships among firms in the design and construction value chain. Specific topics include: industry analysis; strategic planning models; human resource strategy; technology strategy; strategy in fragmented industries; and resource allocation. Case method of instruction is used, supplemented by extensive readings.
J. Macomber

1.461 Corporate Organization For the Future

Prereq.: Permission of instructor
G (Spring)
2-0-4 H-LEVEL Grad Credit

Exploration of emerging trends which are changing the nature of the engineering and construction market and the implications of these changes on corporate organization and management in the engineering and construction industry. Case study of an actual corporate reorganization is used to illustrate and analyze: strategic management documents; growth strategies; executive level management roles and responsibilities; and critical operational and financial control requirements.
R. W. Page

1.462 Marketing Client-Oriented Services

Prereq.: Permission of instructor
G (Fall)
2-0-4 H-LEVEL Grad Credit

Investigates the design, construction and management needs of building sector clients in the 1990s. The basic strategic marketing program, its interrelationship with the remainder of the organization, and its essential role in the design and construction industry are discussed. Subject includes guest lectures by construction owners, designers, and contractors and a team project to develop business and marketing plans for providing and implementing services in various project stages.
J. F. Kennedy

1.471 Management of Large-Scale Systems

Prereq.: —
G (Spring)
2-0-4

Provides an overview of current practices and methods for managing the engineering, procurement and construction of large-scale infrastructure project. Each year an engineering firm, construction firm, government owner, or private owner is invited to present a series of lectures on actual case examples. For the past several years, Boston's Central Artery/Tunnel Project has been the topic of the subject. Information: C. H. Helliwell.

1.472 Innovative Contract Strategies in the Public and Private Sectors

Prereq.: Permission of instructor
G (Spring)
2-0-4 H-LEVEL Grad Credit

Examines the compatibility of various construction contracting methods, consisting of organizations, contracts, and award methods, with certain types of projects and owners. Six methods are examined: (1) traditional general contracting; (2) construction management; (3) multiple primes; (4) design-build; (5) turnkey; and (6) build-operate-transfer. Subject includes lectures, case studies, guest speakers, and a team project to analyze an actual case example.
C. M. Gordon

1.481 Research Seminar in Construction Engineering and Management

Prereq.: —
G (Fall, Spring)
1-0-2 [P/D/F]
Can be repeated for credit

Seminar intended mainly for master's and doctoral candidates in the Center for Construction Research and Education. Oral and written presentation by students on thesis activities and by faculty on research topics.
C. H. Helliwell

1.482 Studies in Construction Engineering and Management

Prereq.: —
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Individual study of an advanced topic in construction engineering and management, selected with approval of faculty supervisor.
F. Moavenzadeh

Materials and Structures

1.50 Structural Engineering

Prereq.: 1.04
U (Fall)
3-2-7

Introduces students to methods for the analysis of statically determinate and indeterminate trusses, beams, and frames. Examples are: method of sections; conjugate beam method; moment distribution; etc. Determination of member forces and structural deformations (displacements); approximate methods; structural stability; energy methods (virtual force method); introduction to matrix methods.
E. Kausel

1.51 Design of Steel Structures

Prereq.: 1.50
U (Spring)
3-2-7

Objective is to develop a solid background in the design principles of steel structures. Emphasis on contemporary design methods using load and resistance factor design. Includes design of structural members, joint, connections, and structural systems.
S. C. Wooh

1.52 Design of Concrete Structures

Prereq.: 1.50
U (Fall)
3-2-7

Objectives are to develop a solid background in the design principles of concrete structures. Emphasis on contemporary design methods using ultimate load design concepts. Includes design of reinforced concrete members for bending, shear, and axial loads, and structural systems.
O. Buyukozturk

1.53 Constructed Facilities Project Laboratory

Prereq.: *1.59*
U (Spring)
1-5-6 Institute LAB

Concepts, techniques, and devices used to measure engineering properties of materials. Emphasis placed on measurement of load-deformation characteristics of common construction materials, both natural and fabricated. Half-semester project devoted to experimental proof of hypothesis on some aspect of testing or behavior. Emphasis placed on approximation of testing errors.
J. T. Germaine

1.541 Behavior of Concrete Structures

Prereq.: 1.52
G (Fall)
3-0-9 H-LEVEL Grad Credit

Strength and deformation of concrete under various states of stress; failure criteria. Fundamental behavior of reinforced concrete structures and their members. Basis for design, and code constraints. High-performance concrete materials and their use in innovative design solutions. Slabs: yield line theory. Behavior models and nonlinear analysis. Complex systems: bridge structures, concrete shells, and containments.
O. Buyukozturk

1.542 Behavior of Steel Structures

Prereq.: 1.51
G (Spring)
3-0-9 H-LEVEL Grad Credit

Conceptual design of steel structural systems. Wind and seismic effects. Design criteria for members and systems. P-Δ effects. Structural connections. Structural analysis versus structural design. Inelastic analysis procedures for stability and limit states. Computer methods for element and system design. Tall-building design considerations.
Information: O. Buyukozturk.

1.543 Planning and Design of Structural Systems

Prereq.: 1.50, 1.51
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-2-7 H-LEVEL Grad Credit

Concerned with the conceptualization and preliminary design of structural systems. Topics include: structural loadings; structural components; horizontal-span building structures; gravity load systems; lateral load systems; tall buildings; shell roof systems; lightweight structures; bridge systems.
J. J. Connor, Jr.

1.56J Structural Mechanics in Nuclear Power Technology

(Same subject as 22.314J, 2.084J, 13.14J)
Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 22.314J.
O. Buyukozturk, J. E. Meyer

1.571 Structural Analysis and Control

Prereq.: 1.51
G (Fall)
3-0-9 H-LEVEL Grad Credit

Computer-based methods for the analysis of large-scale structural systems. Modeling strategies for complex structures. Application to tall buildings, cable-stayed bridges, and tension structures. Introduction to the theory of structural control. Design and implementation of control algorithms for structural systems subjected to quasi-static loading.
J. J. Connor, Jr.

1.573J Introduction to Structural Mechanics

(Same subject as 13.10J)
Prereq.: 2.01 or 2.001, 18.03
G (Fall)
4-0-8 H-LEVEL Grad Credit

See description under subject 13.10J.
N. M. Patrikalakis, J. J. Connor, Jr.

1.581 Advanced Structural Dynamics

Prereq.: 1.50 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Comprehensive subject on the analysis of structural systems for dynamic loads. General formulation for discrete and continuous systems. Free vibrations and normal modes. Forced vibrations induced by structural loads or by ground motions. Viscous and hysteretic damping. Solutions in the time domain: convolution, modal superposition, time-step integration. Solutions in the frequency domain using the fast Fourier transform. Elements of structural control theory, classical optimal control. Discrete time control. Application to buildings.
E. Kausel, J. J. Connor, Jr.

1.583 Nondestructive Evaluation of Materials and Structures
(Revised Units)

Prereq.: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

Overview of principles and applications of the state-of-the-art NDE methods. Special emphasis on ultrasonics: fundamental wave motion in solids and fluids, transducers, imaging and quantitative measurements, signal processing, and basic instrumentation. Applications: flaw detection, materials characterization, composite materials and structures.
S. C. Wooh

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.

1.59 Mechanics of Construction Materials

Prereq.: 1.04
U (Spring)
3-0-6

Develops an understanding of the mechanical behavior of construction materials. Includes study of elastic, plastic, and time-dependent behavior. Deterioration and failure mechanisms, failure criteria. Applications include cementitious materials, steel, timber, polymer, pavement materials, and composites. Materials selection.
C. Leung

1.591J Fracture of Structural Materials

(Same subject as 3.90J, 13.16J)
Prereq.: 2.30 or 3.11 or 13.15
G (Fall)
3-0-6 H-LEVEL Grad Credit

See description under subject 3.90J.
F. J. McGarry, K. Masubuchi

1.592 Mechanical Behavior of Construction Materials

Prereq.: —
G (Spring)
3-2-7 H-LEVEL Grad Credit

Develops an understanding of material behavior based on microstructural mechanisms of deformation and failure. Includes study of elastic, plastic, creep, fracture, and durability behavior. Applications to traditional construction materials (steel, concrete, and timber) as well as recent developments in high-performance civil engineering materials.
C. Leung

1.593J Mechanical Behavior of Plastics

(Same subject as 3.91J)
Prereq.: 3.064
G (Spring)
3-2-4 H-LEVEL Grad Credit

See description under subject 3.91J.
F. J. McGarry, D. K. Roylance

1.594J Composite Materials

(Same subject as 3.92J)
Prereq.: 3.064
G (Fall)
3-2-4 H-LEVEL Grad Credit

See description under subject 3.92J.
F. J. McGarry

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: L. J. Gibson.

Hydrodynamics and Coastal Engineering

1.60 Environmental Fluid Transport Processes

(Subject meets with 1.61)
Prereq.: 1.05 or 2.20 or 10.301 or equivalent
U (Fall)
4-0-8

1.61 Environmental Fluid Transport Processes

(Subject meets with 1.60)
Prereq.: 1.05 or 2.20 or 10.301 or equivalent
G (Fall)
4-0-8

Introduction to transport of momentum, mass, and heat in water and air based on differential form of conservation equations. Creeping, laminar, and turbulent flows. Molecular and turbulent diffusion, mixing and dispersion in the fluid environment. Boundary layers and boundary conditions. Transport of conservative and non-conservative substances. Useful for students with little or no fluids background interested in developing a greater physical intuition for basic fluid movement and transport processes relevant to the environment. Graduate level includes additional homework in the form of reviews of relevant journal and practical articles.
H. M. Nepf

1.63 Topics in Environmental Fluid Dynamics

Prereq.: 1.60, 1.131 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Theoretical topics of environmental fluid dynamics over a wide variety of scales. Details of low Reynolds flows around a sphere, and implications on coagulation and Brownian diffusion. Transient and oscillatory boundary layers. Induced streaming and mass transport. Dispersion in wave boundary layers. Applications of complex variables to potential flows and seepage flows. Convection and instability in flow through porous media. Effects of earth rotation. Coriolis force and effects on waves. Friction and wind. Ekman boundary layer, Ekman pumping and quasi-geostripic flows. Tidal boundary layers.
C. C. Mei

1.64 Dynamics of Stratified Fluids

Prereq.: 1.60
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-6 H-LEVEL Grad Credit

Introduction to the dynamic effects of stratification in natural fluid flows. Topics include: internal wave dynamics; double-diffusion; buoyant jets and plumes; vertical mixing and turbulent boundary layers in stratified fluids; instability and turbulance in stratified shear flows.
H. M. 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

Advanced topics selected by students for individual study with staff approval. Choice of subjects from theoretical, experimental, and practical phases of hydromechanics, hydraulic engineering, water resources, hydrology, and environmental engineering.
Information: H. F. Hemond.

1.67 Sediment Transport and Coastal Processes

Prereq.: 1.60, *1.69*
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-6 H-LEVEL Grad Credit

Emphasizes the quantitative description of the mechanics of sediment transport in steady and unsteady flows based on hydrodynamic principles. Equations of motion for particles in a turbulent flow, entrainment, bedload, and suspended load. Bedform mechanics, ripples, dunes. Flow resistance and boundary-layer mechanics. Wave-induced longshore currents, longshore and on-offshore sediment transport. Coastal protection. Basic theory of water waves assumed known; contact instructor in late August if this presents a problem.
O. S. Madsen

1.69 Introduction to Coastal Engineering

Prereq.: 1.60
G (Fall)
3-0-6 H-LEVEL Grad Credit

Basic hydrodynamics of waves in deep and shallow water. Linear theory, dispersion, superposition, spectral representation. Energy, energy transport, dissipation by bottom friction. Refraction, diffraction by breakwaters. Some nonlinear aspects, wave breaking. Emphasizes physical interpretation of mathematical results and their engineering application. Storm surges, coastal circulation, forecasting of wind-wave characteristics. Wind-wave statistics, wave forces on piles; breakwater stability.
O. S. Madsen

1.691 Surface Wave Dynamics

Prereq.: 1.131, 1.69, or equivalent
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Dynamics of surface gravity waves in coastal seas. Emphasizes mechanical principles and theoretical methods of analysis. Ray theory of refraction, wave interaction with longshore bars, scattering of shallow-water waves, linearized theory of harbor oscillation. Diffraction by large bodies. Transient aspects of dispersion and tsunamis. Radiation stresses and short-wave/long-wave interactions. Nonlinear modulation of short waves and instability. Solitons and harmonic generation.
C. C. Mei

1.697J Oceanographic Systems I

(Same subject as 13.990J)
Prereq.: —
G (Summer)
2-4-6

See description under subject 13.990J.
(Woods Hole Staff), J. F. Lynch

1.698J Oceanographic Systems II

(Same subject as 13.991J)
Prereq.: —
G (Summer)
2-4-6

See description under subject 13.991J.
(Woods Hole Staff)

1.699J Special Projects in Oceanographic Engineering

(Same subject as 13.999J)
Prereq.: Permission of instructor
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

See description under subject 13.999J.
(Woods Hole Staff)

Hydrology and Water Resource Systems

1.70 Environmental Engineering Clinic

Prereq.: Permission of instructor
U (Spring)
2-8-2
Can be repeated for credit

Designed to expose students to real-world environmental engineering projects and potential employment opportunities. A list of clinic projects — encompassing physical, chemical, and biological aspects of environmental engineering — has been developed in consultation with private and public "sponsors" (local consulting firms, state agencies, etc.). Students select a project, and work jointly with an individual from the sponsoring firm and an MIT faculty member. Requires comprehensive written report and oral presentation.
E. E. Adams

1.71J Introduction to Hydrology

(Same subject as 12.320J)
Prereq.: 1.03, 1.05, or equivalents
U (Fall)
3-0-9

The hydrologic cycle and relevant atmospheric processes; water and energy balance; radiation; precipitation formation; evaporation; transpiration by vegetation; infiltration and storm runoff processes. Groundwater flow and the hydraulics of wells. Routing of runoff and flood water. Probabilistic analysis and extreme-value theory for determination of flood hazard. Data analysis and design in water resource engineering.
D. Entekhabi

1.711 Engineering Hydrology

Prereq.: 1.03, 1.05, 1.71J
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-6 H-LEVEL Grad Credit

Models of hydrologic processes for selected engineering applications. Rainfall-runoff models, flood routing, urban hydrology, flood/drought frequency analysis, loss estimation, groundwater models, and storage analysis. Data sources for hydrologic models: instrumentation, measurement systems, remote sensing. Model limitations and the research-practice gap.
Consult D. McLaughlin.

1.713J Land-Atmosphere Interaction

(Same subject as 12.826J)
Prereq.: 1.71J or 1.714 or permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Exchange of mass, heat, and momentum between the soil, vegetation, or water surface and the overlying atmosphere; flux and transport in the turbulent boundary layer; coupled balance of moisture and energy. Hydrothermal flux and storage in unsaturated porous media. Evapotranspiration, infiltration, and hillslope processes. Diagnostics of global cycle of water and energy. Remote sensing techniques and *in situ* observation techniques. Introduction to numerical models of coupled atmospheric and hydrologic processes at local, regional, and global scales.
D. Entekhabi

1.714 Surface Hydrology

Prereq.: 1.71J or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Covers observations and theory of the physical processes involved in the hydrologic cycle. Processes considered include atmospheric radiation and transport, rainfall, infiltration, runoff generation, stream flow, evaporation, transpiration, rainfall interception, and snow processes. Problem sets, a short term paper, and a final examination.
E. A. B. Eltahir

1.715 Environmental Data Analysis

Prereq.: 1.03 or equivalent
G (Fall)
3-0-9 H-LEVEL Grad Credit

Covers probabilistic concepts and techniques that are useful for environmental data analysis. The topics include: random variables; hypothesis testing; linear regression, analysis of trends; space/time domain analysis; frequency domain analysis; simulation of random fields; Markovian processes; derived distributions; and stochastic differential equations. Problem sets emphasize environmental applications.
E. A. B. Eltahir

1.72 Groundwater Hydrology

Prereq.: 1.60
G (Fall)
3-1-8 H-LEVEL Grad Credit

Introduces subsurface flow theory and applications; storage properties, Darcy equation, flow nets, mass conservation, the aquifer flow equation, heterogeneity and anisotropy, regional vertical circulation, unsaturated flow, and recharge. Well hydraulics, stream-aquifer interaction, distributed- and lumped-parameter numerical models. Groundwater quality, mixing cell models, contaminant transport processes, dispersion, decay and adsorption; pollution sources. Includes laboratory and computer demonstrations. Core requirement for Environmental and Geoenvironmental M.Eng. program.
L. W. Gelhar

1.721 Advanced Subsurface Hydrology

Prereq.: 1.72, 18.075, permission of instructor
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Advanced treatment of flow in natural porous media with applications to resource development and environmental protection. Fluid transport processes in deformable media, boundary conditions, and problem formulation. Stochastic treatment of temporal and spatial variability. Contaminant transport, macrodispersion, tracer tests, salt water intrusion, heat transport, unsaturated flow and solute transport, flow and transport in fractured rocks. Large-scale behavior of heterogeneous media and uncertainty in model predictions.
L. W. Gelhar

1.723 Groundwater Quality and Remediation (Revised Content)

Prereq.: 1.72
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Principles and applications of contaminant transport and transformation processes relating to subsurface water as a natural resource; sources of contamination, drinking water standards and risk, advection, dispersion, transformation, retardation and attenuation of solutes; vadose zone transport, multiphase flows, NAPL transport, colloidal transport, sorption, volatilization, chemical equilibrium reactions, and biodegradation; simulation of reactive transport, field-scale processes and heterogeneity, site characterization and disposal risk assessment models. Alternate years.
L.W. Gelhar

1.724 Groundwater Modeling

Prereq.: 1.72, 18.03 or equivalent
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Fundamentals and applications of numerical modeling to groundwater systems. Groundwater modling is presented as a process in which numerical solutions of the governing groundwater flow and contaminant transport equations are developed as part of an integrated approach that incorporates issues such as data requirements, natural heterogeneities, and interpretation of modeling results. Discretization techniques, different numerical methods and reactive contaminant transport, calibration targets, sensitivity analysis, and modeling limitations. Alternate years.
D. McLaughlin

1.725J Chemicals in the Environment: Fate and Transport

(Same subject as TPP.51J)
Prereq.: Permission of instructor
G (Fall)
3-0-9

For Institute students in all departments interested in the behavior of chemicals in the environment (see TPP listings for other subjects). Emphasis on man-made chemicals, their movement through water, air, and soil, and their eventual fate. Physical transport, as well as chemical and biological sources and sinks, are discussed. Linkages to health effects, sources and control, and policy aspects. Core requirement for Environmental M.Eng. program.
H. F. Hemond

1.731 Water Resource Systems

Prereq.: 1.72, 1.714, 18.03 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Survey of deterministic optimization methods for management of large-scale water projects. Linear, integer, nonlinear, and dynamic programming illustrated with case studies. Applications include reservoir and irrigation development, conjunctive use of surface and groundwater, and hazardous waste remediation.
D. McLaughlin

1.732 Hydrologic Estimation and Prediction

Prereq.: 1.715
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-9 H-LEVEL Grad Credit

Quantitative methods for describing uncertainty and natural variability. Estimating unobservable physical parameters from field measurements. Real-time forecasting and control. Environmental data assimilation. Case studies include stream flow forecasting, reservoir operations, characterization of subsurface contamination.
D. McLaughlin

Aquatic Sciences, Water Quality Control, and Environmental Management

1.75 Limnology and Wetland Ecology

Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Dominant physical, chemical, and biological features of lakes and wetlands: basin geology, water budget, wind-driven hydromechanical phenomena, heat balance, thermal stratification, radiation environment, biological communities, and cycles of major elements. Characterization of wetlands, wetland biota, and chemical conditions of wetlands. Methodologies of modern limnology, including field methods and use of models; and current issues in lake and wetland management. Alternate years.
H. F. Hemond

1.76 Aquatic Chemistry

Prereq.: 5.11
G (Fall)
3-0-9 H-LEVEL Grad Credit

Quantitative treatment of chemical processes in aquatic systems. A brief review of chemical thermodynamics and kinetics is followed by studies of acid-base, precipitation-dissolution, coordination, and reduction-oxidation reactions of interest in systems such as lakes, oceans, rivers, estuaries, groundwaters, and wastewaters. Emphasis on equilibrium calculations in model systems as a tool for understanding the variables that govern the chemical composition of aquatic systems and the fate of inorganic pollutants. 5.60 is a suggested prerequisite. Suitable for advanced undergraduates.
B. Voelker

1.761 Environmental Chemical Kinetics
(New)

Prereq.: 1.76 or permission of instructor
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Advanced subject emphasizing kinetics and mechanisms of chemical processes in aquatic systems such as surface waters, groundwaters, wastewaters, and cloudwaters. Topics include coordination and redox chemistry, reactions at the solid-solution interface (such as formation and dissolution of minerals, coagulation, and sorption), photochemistry, and radical chemistry. Offered alternate years.
B. Voelker

1.77 Water Quality Control

Prereq.: 1.05
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 M.Eng. program.
E. E. Adams

1.782 Environmental and Geoenvironmental Engineering M.Eng. Project
(Revised Units)

Prereq.: Limited to Course 1 M.Eng. Students
G (Fall, IAP, Spring)
5-0-10

Core requirement for Environmental and Geoenvironmental M.Eng. program. Designed to teach about environmental restoration engineering through the use of case studies, computer software tools, and seminars from industrial experts. The MMR Superfund site located at Otis Air National Guard Base is the case study on which lectures and student projects are based. Topics include groundwater modeling theory, legislative framework and regulations, geotechnical engieering, environmental chemistry, risk analysis and risk management, remediation goals, site characterization, remediation technologies, site closure and pollution prevention. Students must register for 1.782 for both IAP and spring term.
F. Perkins

1.80 Fundamentals of Ecology
(Revised Units)

Prereq.: —
U (Fall)
3-1-8 REST

Basic subject dealing with the science of ecology; principles of interrelationships between organisms and their environment. Development of basic concepts of energy flow and biogeochemical cycles in ecosystems; productivity; trophic dynamics; community structure and stability; competition and predation; evolution and natural selection; population growth; and physiological ecology. Emphasis on aquatic systems.
S.W. Chisholm

1.81J Chemicals in the Environment: Toxicology

(Same subject as TOX.104J, TPP.53J)
Prereq.: 5.11, 7.012/7.013/7.014
U (Spring)
3-0-9

See description under subject TOX.104J.
W. G. Thilly

1.811J Environmental Law: Pollution Control

(Same subject as TPP.33J)
Prereq.: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

Reviews and analyzes Federal and state regulation of air and water pollution and hazardous wastes. Emphasizes use of legal mechanisms and alternative approaches (such as economic incentives) to control pollution and encourage chemical accident and pollution prevention. Focuses on the major Federal legislation, the underlying administrative system, and the common law in analyzing the goals of pollution control and pollution prevention, economic consequences, and the role of the courts. Discusses both classical pollutants and toxic industrial chemicals. Also provides an introduction to basic legal skills.
N. A. Ashford, C. C. Caldart

1.812J Regulation of Chemicals, Radiation, and Biotechnology

(Same subject as TPP.34J)
Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Focuses on policy design and evaluation in the regulation of hazardous substances and processes. Includes risk assessment, hazardous chemical wastes, toxic air and water pollutants, pesticides, food additives, pharmaceuticals, radiation and radioactive wastes, product safety, the Toxic Substances Control Act, workplace hazards, indoor air pollution, biotechnology, and victims' compensation. Both health and economic consequences of regulation discussed.
N. A. Ashford, C. C. Caldart

1.814J Industrial Ecology

(Same subject as TPP.123J, 3.560J)
Prereq.: TPP.11 or 3.56
G (Spring)
3-0-6 H-LEVEL Grad Credit

See description under subject TPP.123J.
J. Clark, F. Field, R. de Neufville

1.82 Problems in Aquatic Biology and Chemistry

Prereq.: Permission of instructor
G (Fall, Spring)
Units arranged [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Advanced topics in fields of aquatic chemistry, aquatic biology, and oceanography. Choice of independent study, seminar, laboratory, or field studies. Typical topics include nutrient and trace-metal interactions with aquatic biota, biogeochemical cycles, current issues in oceanography.
S. W. Chisholm

1.83 Environmental Organic Chemistry

Prereq.: 5.12, 5.60
G (Spring)
3-0-9 H-LEVEL Grad Credit

Focuses on the processes affecting anthropogenic organic compounds in the environment. Uses physical chemical properties to predict chemical transfers between environmental compartments (air, water, sediments, 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 hazardous and natural organic compounds.
P. M. Gschwend

1.85 Wastewater Treatment Engineering

Prereq.: 1.05 or 1.80
G (Spring)
3-0-6

Theory and design of systems for treating municipal wastewater. Methods for characterizing wastewater properties. Physical, chemical, and biological processes, including primary treatment, and suspended growth and fixed-film methods for secondary treatment. Nutrient removal. Reactor design and process kinetics. State-of-the-art processes. Sludge processing and disposal. Field trip to local wastewater treatment plant.
A. Pincince

1.89 Environmental Microbiology

Prereq.: —
G (Spring)
3-0-9 H-LEVEL Grad Credit

A general microbiology subject dealing with the function of microorganisms in environmental processes. Topics include microbial cell structure, bioenergetics, microbial growth, macromolecular structures, microbial fermentations, elemental cycles, microbial ecology, biodegradation of wastes, and metal transformations.
Staff

Special Studies

1.UR Research in Civil and Environmental Engineering

Prereq.: —
U (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit

1.URG Research in Civil and Environmental Engineering

Prereq.: —
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.
Information: A. J. Whittle.

1.91 Civil and Environmental Engineering Internship

Prereq.: —
U (Fall, Spring, Summer)
0-6-0 [P/D/F]

1.92 Advanced Civil and Environmental Engineering Internship

Prereq.: 1.91
G (Fall, Spring, Summer)
0-6-0 [P/D/F]

1.91 provides credit for the first two work assignments of Course I students affiliated with the Engineering Internship Program. 1.92 provides credit for the third and fourth work assignments for students affiliated with the Engineering Internship Program. Students register for both 1.91 and 1.92 twice and must complete both work assignments in order to receive academic credit for the subjects. Enrollment limited to students registered in the Course I Internship Option.
Information: O. Buyukozturk.

1.ThG Graduate Thesis

Prereq.: —
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Program of graduate research, leading to the writing of an S.M., M.Eng., C.E., Ph.D., or Sc.D. thesis; to be arranged by the student and an appropriate MIT faculty member. Consult Department Academic Programs Office. Consult Department Academic Programs Office.

1.961–1.966 Special Graduate Studies in Civil and Environmental Engineering

Prereq.: Permission of instructor
G (Fall, Spring)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Graduate subjects taught experimentally; special subjects offered by visiting faculty; seminars on topics of current interest.
Information: J. Sussman.

1.968 Graduate Studies in Civil and Environmental Engineering

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

Individual study, research, or laboratory investigations at the graduate level, under faculty supervision.
Information: J. Sussman.

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.
Information: J. Sussman.

1.970–1.977 Special Graduate Studies in Civil and Environmental Engineering

Prereq.: Permission of instructor
G (Fall, IAP, Spring)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Graduate subjects taught experimentally; special subjects offered by visiting faculty; seminars on topics of current interest.
Information: J. Sussman.

1.978–1.979 Special Graduate Studies in Civil and Environmental Engineering

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

Graduate subjects taught experimentally; special subjects offered by visiting faculty; seminars on topics of current interest. 1.978 is taught P/D/F.
Information: J. Sussman.

1.980J Thesis Proposal Seminar

(Same subject as TPP.14J)
Prereq.: Thesis Registration
G (Fall, IAP)
1-0-2 H-LEVEL Grad Credit
Can be repeated for credit

See description under subject TPP.14J.
R. de Neufville, J. Ehrenfeld, R. Tabors

1.982 Research in Civil and Environmental Engineering

Prereq.: —
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]

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 I.
J. Sussman

1.983 Teaching in Civil and Environmental Engineering

Prereq.: —
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]

For teaching assistants in recognition of 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 I.
J. Sussman

1.991, 1.992 Special Undergraduate Studies in Civil and Environmental Engineering

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

Undergraduate subjects taught experimentally; special subjects offered by visiting faculty; seminars on topics of current interest. 1.991 is taught P/D/F.
Information: O. S. Madsen.

1.993–1.995 Special Undergraduate Studies in Civil and Environmental Engineering

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

Undergraduate subjects taught experimentally; special subjects offered by visiting faculty; seminars on topics of current interest. 1.995 is graded. Other numbers are taught P/D/F.
Information: O. S. Madsen.

1.999 Undergraduate Studies in Civil and Environmental Engineering

Prereq.: —
U (Fall, Spring, Summer)
Units arranged
Can be repeated for credit

Individual study, research, or laboratory investigations under faculty supervision.
Information: O. S. Madsen.

Course 2

Mechanical Engineering

For degree requirements, see listing in Chapter VII under the School of Engineering.

2.UR Undergraduate Research in Mechanical Engineering

Prereq.: —
U (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit

2.URG Undergraduate Research in Mechanical Engineering

Prereq.: —
U (Fall, Spring, Summer)
Units arranged
Can be repeated for credit

Individual study, research, or laboratory investigations under faculty supervision, including individual participation in an ongoing research project. See projects listing in Undergraduate Office, 1-104, for guidance.
Coordinator: D. Rowell.

2.001 Mechanics and Materials I
(Revised Units)

Prereq.: 8.01, 18.02
U (Fall, Spring)
3-1-5 REST

Introduction to statics and the mechanics of deformable solids. Emphasis on the three basic principles of equilibrium, geometric compatibility, and material behavior. Stress and its relation to force and moment; strain and its relation to displacement; linear elasticity with thermal expansion. Failure modes. Application to simple engineering structures such as rods, shafts, beams, and trusses. Application to design.
R. Abeyaratne, F. Feng, D. M. Parks

2.002 Mechanics and Materials II
(Revised Units)

Prereq.: 2.001
U (Fall, Spring)
3-2-7

Introduces mechanical behavior of engineering materials, and the use of materials in mechanical design. Emphasizes the fundamentals of mechanical behavior of materials, as well as design with materials. Major topics: elasticity, plasticity, limit analysis, fatigue, fracture, and composites. Materials selection. Laboratory experiments involving projects related to materials in mechanical design.
L. Anand, D. M. Parks, M. C. Boyce

2.003 Systems Modeling and Dynamics I

Prereq.: 8.01, 18.02
U (Fall, Spring)
4-0-8 REST

Introduction to physical system dynamics, emphasizing the common dynamic behavior of mechanical, electrical, fluid, and thermal devices and how they interact. Unified mathematical modeling using linear and non-linear lumped multiport elements. Introduction to matrix methods and computer analysis of system dynamics. Concept of state and formulation of state equations. Dynamic response and stability of linear systems. Frequency response functions, pole-zero configurations, and their interpretation. Generalized impedance and source equivalents. Extensive use of engineering examples.
D. Rowell

2.004J Systems Modeling and Dynamics II
(Revised Units)

(Same subject as 2.03J, 13.013J)
Prereq.: 2.001 and 2.003 or 13.015
U (Fall, Spring)
4-0-5

Introduction to dynamics and vibration of lumped-parameter models of mechanical systems. Distinction between force-momentum and work-energy formulations. Three-dimensional particle kinematics. Newton-Euler equations. Lagrange's equations. Historical citations. Issues of perspective including relationships of dynamics to design.
J. H. Williams, Jr., J. K. Vandiver

2.005 Thermal-Fluids Engineering I

Prereq.: 8.02, *18.03*
U (Fall, Spring)
4-0-8 REST

Equilibrium thermodynamics and its application to engineering systems involving energy exchange and conversion. Concepts of work, heat, and internal energy; The First Law. Reversibility, entropy, and The Second Law. Thermodynamics of state of pure substances. Applications to processes and power cycles. Modes of heat transfer. Conduction, applications using lumped capacity and thermal resistance concepts, finned surfaces. Elements of radiation.
J. Brisson, J. Heywood

2.006 Thermal-Fluids Engineering II

Prereq.: 2.005, 18.03
U (Fall, Spring)
4-0-8

Mechanics of incompressible flow in engineering systems. Hydrostatics. Mass conservation. Inviscid flow analysis and Bernoulli equation. Linear and angular momentum. Application to fluid machines. Analysis of laminar viscous flow in channels and passages. Turbulence. Head loss in pipes. Boundary layers, drag. Forced and natural convective heat transfer in laminar and turbulent flow in channels and over surfaces. Heat exchangers.
R. Kamm

2.007 Design and Manufacturing I

Prereq.: 2.670
U (Spring)
3-3-6

Develops students' competence and self-confidence as designers. Emphasis on the creative design process for individuals. Synthesis, analysis, and robustness as complements. Subject relies on active learning through exercises in lecture and laboratory. A major design-and-build project is featured. Lecture topics include idea generation, estimation, concept selection, visual thinking and communication, kinematics of mechanisms, design for manufacturing, and designer's professional responsibilities. Several manufacturing techniques featured in 2.008 are used in fabrication of designs.
A. H. Slocum

2.008 Design and Manufacturing II

Prereq.: 2.001, 2.003, 2.007, *2.005*
U (Fall, Spring)
3-5-4 Institute LAB

Integration of design, engineering, and management disciplines and practices for analysis and design of manufacturing enterprises. Emphasis is on the physics and stochastic nature of manufacturing processes and systems, and their effects on quality, rate, cost, and flexibility. Topics include process physics and control, design for manufacturing, and manufacturing systems. Group project requires design and fabrication of parts using mass-production and assembly methods to produce a product in quantity. Six units may be applied to the General Institute Lab Requirement.
J.-H. Chun, E. M. Sachs

2.010 Control System Principles
(New)

Prereq.: 2.003, 18.03, *2.004*
U (Fall, Spring)
3-2-4

Introduction to feedback control of physical system behavior. State-space and functional descriptions of linear and nonlinear systems. Feedback, stability, and robustness. Poles and zeroes. Transient response shaping. Natural frequencies, normal coordinates, and modes. Full-state and output feedback. Frequency response methods. Root locus. Bode plots. Stability margins. Design of PID controllers and compensators. Introduction to digital control. Extensive case studies emphasizing computer analysis and design of electromechanical, pneumatic, hydraulic, and electronic control systems.
A. M. Annaswamy

Mechanics, Dynamics, and Acoustics

2.03J Dynamics

(Same subject as 2.004J, 13.013J)
Prereq.: *2.001*, 2.004, and 2.02 or 2.003, 18.03
Acad Year 1996-97: U (Fall, Spring)
Acad Year 1997-98: **Not offered**
4-0-8

See description under subject 2.004J.
J. H. Williams, Jr., J. K. Vandiver

2.032 Dynamics

Prereq.: 2.03J
G (Fall)
3-0-9 H-LEVEL Grad Credit

Momentum principles and energy principles. Lagrange's equations, Hamilton's principle. Applications to mechanical systems including gyroscopic effects. Study of steady motions and nature of small deviations therefrom. Natural modes and natural frequencies for continuous and lumped parameter systems. Forced vibrations. Dynamic stability theory. Causes of instability.
J. H. Williams, Jr.

2.034 Nonlinear Dynamics

Prereq.: 2.032
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

A unified treatment of nonlinear phenomena in the dynamics of discrete and continuous systems. Qualitative methods of analysis, phase plane techniques. Quantitative analysis of weakly nonlinear systems in free and forced vibrations; perturbation methods, nonlinear resonances, self-excited oscillations, lock-in phenomena. Introduction to nonlinear stability and bifurcation theory, chaotic behavior, nonlinear wave propagation, solitons. Applications are made to mechanical, fluid, electrical, and flow-structure interaction problems.
T. R. Akylas

2.05 Kinematics and Dynamics of Mechanisms and Manipulators

Prereq.: 2.03J
G (Fall)
3-0-9 H-LEVEL Grad Credit

Analyzes kinematic and dynamic characteristics of planar and spatial mechanisms, including machines and robotic manipulators. Use of vector, graphical, and 4 by 4 matrix methods for kinematic analysis. An introduction to graphical and computer methods for kinematic synthesis of mechanisms. Methods for dynamic analysis of mechanisms, and the use of digital simulation techniques. Systems include rigid and flexible elements and active control systems. Applications from industrial machine systems and robotic manipulators.
S. Dubowsky

2.06J Mechanical Vibration
(Revised Units)

(Same subject as 13.80J, 13.801)
Prereq.: 2.004J
U (Spring)
3-1-8

Elective unit distribution: Advanced disciplinary, 9; Lab, 3. See description under subject 13.80J.
F. Feng, J. K. Vandiver

2.060J Principles of Acoustics

(Same subject as 13.81J)
Prereq.: 13.013J or 2.03J or 16.040, 18.075
G (Fall)
3-0-9 H-LEVEL Grad Credit

With subject 2.063J, forms a two-term sequence of advanced acoustics; to be taken in either order. Acoustics of fluids, sources of sound, radiation, diffraction and scattering. Energy density and intensity, radiation impedance and directivity. Reciprocity.
Staff

2.061 Random Vibration

Prereq.: 2.03J, 18.075
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Description of stochastic processes. Impulse response and frequency response of linear time-invariant dynamic systems. Correlations and spectra of stationary response. Crossing rates, peaks, and envelopes. Failure under random loading. Poisson pulse processes. Measurement, identification, and response problems. Coherence. Space-time correlations and cross-spectra. Digital data processing. Spectral analysis. Applications to vehicles and structures subjected to wide-band random excitation.
F. Feng

2.062 Wave Propagation

Prereq.: 2.03J
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Wave concepts in applied mechanics with examples chosen from elasticity, acoustics, geophysics, hydrodynamics, and related subjects. Plane wave theory, dispersion, phase and group velocities, wave impedance, energy density and intensity. Theory of characteristics. Reflection and refraction, wave guides, and boundary waves. WKB method, Green's law, and wave action. Generation, transmission, and reception of waves. Water waves, Rayleigh waves, waves in periodic structures.
T. R. Akylas

2.063J Sound and Structural Vibration

(Same subject as 13.82J)
Prereq.: 2.03J or 16.040 or 18.075
G (Spring)
3-0-9 H-LEVEL Grad Credit

With subject 2.060J, forms a two-term sequence in acoustics at advanced level; to be taken in either order. Transmission of vibration in structures and interaction with sound fields. Dynamics of sound fields and longitudinal, shear, and flexural vibrations. Normal modes, phase and group velocity, energy decay. Radiation impedance and input and transfer mobility of structural elements. Statistical energy analysis, reciprocity, energy sharing between structures and sound fields.
Staff

2.067J Structural Acoustics

(Same subject as 13.83J)
Prereq.: —
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-9 H-LEVEL Grad Credit

This advanced-level subject deals with various topics in the transmission of vibrational energy through structures, and the interaction of structural vibrations with surrounding and contained fluid regions. Faculty members will lead discussions of these topics using published papers and research reports. Topics will vary depending on research activities in the Structural Acoustics Program. A good background in dynamics, applied mathematics, and structural mechanics will be assumed. Background courses in acoustics and structural wave propagation are recommended.
Staff

2.072 Mechanics of Continuous Media

Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Principles and applications of continuum mechanics. Kinematics of deformation. Thermomechanical conservation laws. Stress and strain measures. Constitutive equations. Solution of some basic problems for various materials as relevant in materials science, geomechanics, fluid dynamics, and structural analysis. Inherently nonlinear phenomena in continuum mechanics.
R. Abeyaratne

2.073 Solid Mechanics — Plasticity and Inelastic Deformation

Prereq.: 2.30
G (Fall)
3-0-9 H-LEVEL Grad Credit

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

2.083 Applied Elasticity

Prereq.: 2.30 or 2.002, *18.03*
G (Fall)
3-0-9 H-LEVEL Grad Credit

Introduction to the theory and applications of elastic solids. Review strain, stress, and stress-strain law. Several of the following topics: Anisotropic material behavior. Piezoelectric materials. Effective properties of composites. Structural mechanics of beams and plates. Energy methods for structures. Two-dimensional problems. Stress concentration at cavities, concentrated loads, cracks, and dislocations. Variational methods and their applications; introduction to the finite element method. Introduction to wave propagation.
J. H. Williams, Jr., R. Abeyaratne

2.084J Structural Mechanics in Nuclear Power Technology

(Same subject as 22.314J, 1.56J, 13.14J)
Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 22.314J.
J. E. Meyer, O. Buyukozturk

2.093 Computer Methods in Dynamics

Prereq.: 2.03J, 18.075
G (Spring)
3-0-9 H-LEVEL Grad Credit

Formulation of finite element methods for analysis of dynamic problems in solids, structures, fluid mechanics, and heat transfer. Computer calculation of matrices and numerical solution of equilibrium equations by direct integration and mode superposition. Effective eigensolution techniques for calculation of frequencies and mode shapes. Digital computer coding techniques and use of an existing general purpose finite element analysis program. Modeling of problems and interpretation of numerical results.
K. J. Bathe

2.094 Finite Element Analysis of Solids and Fluids

Prereq.: 2.01 or 2.001, 18.075
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Basic principles of continuum mechanics and finite element methods, modern application to solution of practical problems in solid, structural, and fluid mechanics, heat and mass transfer, other field problems. Kinematics of deformation, strain and stress measures, constitutive relations, conservation laws, virtual work, and variational principles. Discretization of governing equations using finite element methods. Solution of central problems using existing computer programs.
K. J. Bathe

System Dynamics and Control

2.100 Information and Probability
(New)

Prereq.: 2.003
U (Fall)
3-0-9

Robots, gas turbines, and toasters share a common feature: they have to get and process information in order to function. Subject provides an introduction to information theory as applied to problems in control, design, and manufacturing. Topics treated include probability and statistics, channel capacity and communications, the characterization and control of noisy systems, the generation and propagation of errors in manufacturing, and the mechanics and design of information-processing devices. Elective unit distribution: advanced disciplinary, 9; design, 3.
S. Lloyd

2.101 Computer Models of Physical and Engineering Systems

Prereq.: 18.03 or 18.034, 1.00
U (Spring)
3-1-8

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
F. Peña-Mora

2.141 Modeling and Simulation of Dynamic Systems

Prereq.: 2.151
G (Fall)
3-0-9 H-LEVEL Grad Credit

Mathematical modeling of complex engineering systems at a level of detail compatible with the design and implementation of modern control systems. Wave-like and diffusive energy transmission systems. Multiport energy storing fields and dissipative fields; consequences of symmetry and asymmetry. Nonlinear mechanics and canonical transformation theory. Examples will include mechanisms, electromechanical transducers, electronic systems, fluid systems, thermal systems, compressible flow processes, chemical processes.
N. Hogan

2.151 Advanced System Dynamics and Control

Prereq.: 2.02 or 2.003, 2.14, 18.06
G (Fall, Spring)
3-0-9 H-LEVEL Grad Credit

Analytical and graphical descriptions of state-determined dynamic physical systems; time and frequency domain representations; system characteristics — controllability, observability, stability; linear and nonlinear system responses. Modification of system characteristics using feedback. State observers, Kalman filters. Modeling/performance trade-offs in control system design. Emphasis on application of techniques to physical systems.
K. Youcef-Toumi, N. Hogan, D. Rowell

2.152 Nonlinear Control System Design

Prereq.: 2.151 or 6.241 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Introduction to applied nonlinear control. Nonlinear stability theory, Lyapunov analysis, Barbalat's lemma. Feedback linearization, internal dynamics. Sliding surfaces. Adaptive nonlinear control. Stable neural network control, multiresolution analysis. Emphasis on applications to physical systems (robots, aircraft, spacecraft, underwater vehicles).
J.-J. E. Slotine

2.153 Adaptive Control: Theory and Applications

Prereq.: 2.151
G (Fall)
3-2-7

A graduate subject on the basic principles of adaptive controllers. Topics include adaptive controllers for first- and second-order systems, strictly positive real-transfer functions, persistent excitation, stability of general adaptive systems, minimum variance and LQ-controllers, n-step ahead predictive controllers, robustness properties, adaptive control of nonlinear systems, and connections to feedback linearization, gain-scheduling, and neural networks. Laboratory exercises pertain to the implementation of adaptive PID controllers in mechanical systems.
A. M. Annaswamy

2.156J Dynamics of Nonlinear Systems

(Same subject as 6.243J, 16.337J)
Prereq.: *18.100*, 6.241
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Alternate years. See description under subject 6.243J.
N. Hogan, J. L. Wyatt, Jr., M. Dahleh, R. Ramnath

2.157J Design and Implementation of Computer-Aided Engineering Systems

(Same subject as 1.127J, 13.471J)
Prereq.: Permission of instructor
G (Fall)
3-2-7 H-LEVEL Grad Credit

Overview of existing CAE systems; architecture of high-performance graphic displays in engineering workstations; orthographic and perspective display transformations; parametric representation of curves and surfaces; elementary differential geometry; interactive graphics; bicubic surface patches; image generation; NC tool paths; solid modeling; advanced research topics; project management for software development. Group projects emphasize CAE system development. Programming proficiency in C required.
D. C. Gossard, N. M. Patrikalakis

2.158J Computational Geometry

(Same subject as 13.472J, 1.128J)
Prereq.: 13.471J/2.157J or 6.837
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 13.472J.
N. M. Patrikalakis, D. C. Gossard

2.159J Computer Aided Engineering I

(Same subject as 1.124J, 13.470J)
Prereq.: 1.00 and knowledge of C
G (Fall)
3-3-6 H-LEVEL Grad Credit

See description under subject 1.124J.
Jn. R. Williams

2.160 Intelligent Control and Sensing

Prereq.: 2.151 or equivalent
G (Fall)
3-2-7 H-LEVEL Grad Credit

Introduces techniques of learning, adaptation, and high-level control. Neural networks; associative memory, multi-layer neural nets, error back propagation, recurrent nets, reinforcement learning, and function approximation using radial basis functions. Introduction to fuzzy sets, fuzzy linguistic control, frame-based systems, and expert control systems. Applications to robots, vehicles, manufacturing processes, and various physical plants. Computer laboratories and term projects. Programming experience is recommended.
H. Asada, J.-J. E. Slotine

2.165 Robotics and Mechatronics

Prereq.: 2.151 and 2.004 or permission of instructor
G (Spring)
3-2-7 H-LEVEL Grad Credit

Dynamic analysis, design, and control of robots and electromechanical systems. Kinematics and dynamics of multi-input, multi-output rigid body systems. Inverse kinematics, inverse dynamics, and computed torque control. Adaptive and learning control. Force feedback, and visual servoing. Programming, task strategy planning, and teleoperation. Actuators, sensors, and component technology. Integrated mechanism/control design; modeling and control of flexible robots and structures. Digital implementation of control algorithms; experiments using table-top robots; term projects; and laboratory demonstrations.
H. Asada, J.-J. E. Slotine, K. Youcef-Toumi

2.171 Analysis and Design of Digital Control Systems

Prereq.: 2.010, 2.151
G (Spring)
3-3-6 H-LEVEL Grad Credit

A comprehensive introduction to control system synthesis in which the digital computer plays a major role, reinforced with hands-on laboratory experience. Covers elements of real-time computer architecture; input-output interfaces and data converters; analysis and synthesis of sampled-data control systems using classical and modern (state-space) methods; analysis of trade-offs in control algorithms for computation speed and quantization effects. Laboratory projects emphasize practical digital servo interfacing and implementation problems with timing, noise, nonlinear devices.
D. Trumper, D. Rowell

2.181J Human Factors Engineering

(Subject meets with 16.453J, 16.400)
Prereq.: *2.010 or 16.060*
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 16.453J.
T. B. Sheridan, L. R. Young

2.182J Human Supervisory Control of Telerobots and Flight Vehicles

(Same subject as 16.422J)
Prereq.: Permission of instructor
G (Spring)
3-1-8 H-LEVEL Grad Credit

Principles of supervisory control and telerobotics. Different levels of automation are discussed, as well as the allocation of roles and authority between humans and machines. Human-vehicle interface design in highly automated systems. Decision aiding. Tradeoffs between human control and human monitoring. Automated alerting systems and human intervention in automatic operation. Enhanced human interface technologies such as virtual presence. Performance, optimization, and social implications of the human-automation system. Examples from aerospace, ground, and undersea vehicles, robotics, and industrial systems.
T. B. Sheridan, R. J. Hansman

2.183 Biomechanics and Neural Control of Movement

Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Normal and pathological sensory-motor behavior of biological systems emerges from a complex interplay of biomechanical and neural factors. Experimentally supported theories of biological motor control, emphasizing manipulation and tool use, are critiqued and compared with robotic approaches. Topics include hierarchical organization, intermittency, optimization theories, kinematic redundancy, neuromuscular dynamics and segmental feedback, "equilibrium-point" theories, instabilities in contact tasks, co-contraction strategies, and impedance control.
N. Hogan

2.192 Engineering Systems Analysis

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

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
R. de Neufville, J. P. Clark, F. Field

Fluid Mechanics and Combustion

2.25 Advanced Fluid Mechanics

Prereq.: 2.006; *18.075 or 18.085*
G (Fall)
4-0-8 H-LEVEL Grad Credit

Survey of principal concepts and methods of fluid dynamics. Mass conservation, momentum and energy equations for continua. Surface tension. Navier-Stokes equations for viscous flows. Similarity and dimensional analysis. Lubrication theory. Boundary layers and separation. Circulation and vorticity theorems. Potential flow. Introduction to turbulence. Lift and drag.
A. A. Sonin

2.273 Turbulent Flow and Transport

Prereq.: 2.25
G (Spring)
3-0-9 H-LEVEL Grad Credit

Turbulent flows, with emphasis on engineering methods. Governing equations for momentum, energy, and species transfer. Turbulence: its production, dissipation, and scaling laws. Averaged (Reynolds) equations for momentum, energy, and species transfer. Simple closure approaches for free and bounded turbulent shear flows: jets, pipe and channel flows, boundary layers, buoyant plumes and thermals, dispersion problems, etc., including heat and species transport as well as flow fields. Introduction to more complex closure schemes and statistical methods in turbulence.
A. A. Sonin

2.274 Computational Fluid Dynamics

Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-9 H-LEVEL Grad Credit

Modern treatment of finite element methods for incompressible viscous fluid flows. Formulation, theoretical analysis, implementation, and application of discretizations and direct/iterative solvers for elliptic, Stokes, convection-diffusion, and Navier-Stokes equations. Finite-difference/finite-element treatment of mixed initial/boundary value problems. Computer assignments requiring programming.
A. T. Patera

2.277 Biomedical Fluid Mechanics

Prereq.: 2.006
G (Spring)
3-0-9 H-LEVEL Grad Credit

Engineering approach to the function of circulatory and respiratory systems and to other problems in physiology involving fluid dynamics. Reviews relevant anatomy and physiology emphasizing quantitative considerations. Presents and discusses mathematical or engineering models in relation to physiological phenomena they are intended to simulate. Directed to graduate students in engineering and science, but open to medical students and undergraduates with the permission of the instructor.
C. F. Dewey, R. D. Kamm

2.280 Fundamentals and Modeling in Combustion

Prereq.: 2.005, 2.006
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Fundamentals and modeling of physical gas dynamics and combustion using analytical and numerical methods. Conservation equations of reacting flows. Chemical thermodynamics and kinetics. Non-equilibrium flow. Detonation and boundary layers. Ignition, flammability, and extinction. Premixed and diffusion flames. Combustion instabilities. Supersonic combustion. Turbulent combustion. Fire, safety, and environmental impact.
A. F. Ghoniem

2.29J Air Pollution Control

(Same subject as 10.571J)
Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 10.571J.
G. J. McRae

Materials

(See also listings under Polymers and Fibers.)

2.30 Mechanical Behavior of Materials
(Revised Units)

Prereq.: 2.001
U (Fall)
3-2-10

Introduces mechanical behavior of engineering materials, and the use of materials in mechanical design. Emphasizes both the fundamentals of mechanical behavior of materials as well as design with materials. Major topics: elasticity, plasticity, limit analysis, fatigue, fracture, and composites. Materials selection. Laboratory experiments involving projects related to materials in mechanical design. Limited enrollment.
L. Anand, D. M. Parks, M. C. Boyce

2.302 Physics of Inelastic Deformation of Solids

Prereq.: 2.30 or 2.002 or 2.305
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Rate mechanisms in crystal plasticity, kinetics and dynamics of slip, superposition of flow stress mechanisms. Inelastic deformation in non-metals, visco-plasticity of metallic, inorganic, and polymeric glasses; plasticity of crystalline polymers; statistical theory of elastomeric behavior. Macro-plasticity in polycrystalline metals and in polymers. Strain hardening and recovery. Macroscopic three-dimensional constitutive relations for inelastic deformation usable in computational mechanics. Alternate years.
A. S. Argon

2.303 Micro Mechanisms of Fracture

Prereq.: 2.30 or 2.002 or 2.305
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Fundamental crack tip solutions. Cohesive strength of pure solids and interfaces. Microcrack initiation. Brittle fracture in tension and compression. Static fatigue. Toughening of brittle solids by crack tip shielding and trapping or bridging. Ductile fracture by plastic cavitation. Intergranular fracture at elevated temperatures. Brittle to ductile transitions in fracture. Fracture under cyclic loading. Fracture of composites. Fracture along interfaces. Examples drawn from all prominent structural solids. Alternate years.
A. S. Argon

2.305 Advanced Mechanical Behavior of Materials

Prereq.: 2.001, 3.091
G (Fall)
3-0-9 H-LEVEL Grad Credit

Fundamentals of the mechanical behavior of engineering materials and their uses in structural and design-related applications is presented, starting from a mechanistic point of view to arrive at phenomenological forms of constitutive behavior for deformation and fracture. Problems involving elasticity, plasticity, creep, visco-elasticity, and monotonic and cyclic fracture are discussed, including applications to material processing.
A. S. Argon, M. C. Boyce

2.306 Dislocations and Mechanical Properties of Crystalline Solids

Prereq.: 2.30 or 2.002, 3.091
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Derivation of properties of both straight and curved dislocations from elasticity. Interaction of dislocations with external stresses, with each other, with free surfaces, interfaces, and cracks. Dislocations in specific crystal structures: stress fields, line energies, line tension. Kinematics of dislocation glide and climb. Dynamics of moving dislocations. Interaction of dislocations with point defects and climb. Dislocation multiplication. Athermal mechanisms of strain hardening in both homogeneous and heterogeneous crystals.
A. S. Argon

2.31 Finite Element Analysis in Computer Aided Mechanical Design
(New)

Prereq.: 2.001, 2.002
U (Spring)
3-3-6

Focuses on the role of finite element analysis in computer aided mechanical design. Introduction to the finite element method for problems involving elastic, thermo-elastic, and elastic-plastic material behavior together with stiffness, strength and toughness-related material properties which limit mechanical design. Approximations inherent in numerical analyses discussed and the physical interpretations of the results emphasized. Projects emphasize the various iterative loops between the different phases of the "design/analysis/manufacture/test" philosophy of mechanical design. Elective unit distribution: Advanced disciplinary, 6; Design, 3; Lab, 3.
M. C. Boyce, L. Anand, D. M. Parks

Thermodynamics and Statistical Mechanics

2.41J Thermal Power Engineering

(Same subject as 13.25J)
Prereq.: 2.005
U (Spring)
3-0-9

Examines current and future thermal power systems. Introduction to combustion and the design of turbomachinery. Analyses of various power plants including Rankine, Brayton, Otto, Diesel, and refrigerating systems. Applications include land-based and marine power plants. Consideration of pollution and environmental issues.
E. G. Cravalho, A. D. Carmichael

2.45J Fundamentals of Energy in Buildings

(Same subject as 4.42J, 1.42J)
Prereq.: 8.02, 18.02
U (Fall)
3-0-9 REST

See description under subject 4.42J.
L. R. Glicksman

2.451J General Thermodynamics

(Same subject as 22.571J)
Prereq.: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

General foundations of thermodynamics valid for small and large systems, and equilibrium and nonequilibrium states. Definitions of work, energy, stable equilibrium, available energy, entropy, thermodynamic potential, and interactions other than work (nonwork, heat, mass transfer). Applications to properties of materials, bulk flow, energy conversion, chemical equilibrium, combustion, and industrial manufacturing.
J. L. Smith

2.46J Analysis and Design of Heating, Ventilating, and Air Conditioning Systems
(New)

(Same subject as 4.427J)
Prereq.: 2.005, 2.51
G (Fall)
3-0-9 H-LEVEL Grad Credit

Explores the fundamentals of heating, ventilating, and air-conditioning (HVAC) systems. Discussion of psychrometrics, air conditioning processes, thermal comfort, indoor air quality and outdoor design conditions; concentration on the calculation of heating and cooling load in order to size suitable HVAC equipment; estimation of energy consumption of the HVAC equipment. Introduces both manual and computer methods. One site visit.
Q. Chen

Heat and Mass Transfer

2.51 Heat and Mass Transfer Engineering

Prereq.: 2.006
U (Fall, Spring)
3-0-9

Analysis, modeling, and design of heat and mass transfer processes in manufacturing, machinery, energy production, and energy management technologies. Heat conduction in solids: steady and transient states, finned surfaces, numerical simulation tools. Heat transfer associated with laminar and turbulent flow of fluids in free and forced convection. Heat transfer in boiling and condensation. Heat exchanger design, including enhanced surface selection and pressure loss evaluation. Mass transfer at low rates: evaporation, wet-bulb temperature, catalysis. Students complete a creative design project on a problem taken from industry. Elective unit distribution: Advanced disciplinary, 9; Design, 3.
J. H. Lienhard, L. R. Glicksman, B. B. Mikić

2.54 Heat Transfer

Prereq.: —
G (Spring)
3-0-3

Fundamentals of conduction, radiation of heat, and effects of convection, with applications to problems arising in practice. Primarily for selected officers of US Navy and Coast Guard.
B. B. Mikić

2.55 Advanced Heat and Mass Transfer

Prereq.: 2.51
G (Spring)
3-0-9 H-LEVEL Grad Credit

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

2.56 Conduction and Change of Phase Heat Transfer

Prereq.: 2.51, *18.075*
G (Fall)
3-0-9 H-LEVEL Grad Credit

Solutions of steady and transient heat conduction problems in orthogonal coordinate systems with various boundary conditions. Approximate methods: application of numerical techniques. Moving boundaries: problems in freezing and melting. Condensation heat transfer. Boiling: mechanisms and heat transfer correlations. Thermal modeling of engineering systems: use of laser in material removal and processing.
B. B. Mikić

2.58J Radiative Transfer
(Revised Units)

(Same subject as 10.74J)
Prereq.: 10.302 or 2.51
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
2-0-4 H-LEVEL Grad Credit

Principles of thermal radiations and their application to engineering heat transfer problems. Basic laws of thermal radiation. Radiative properties of surfaces. Radiant interchange among surfaces separated by a transparent medium. Thermal radiation characteristics of gases and particle clouds. Radiative interchange through absorbing, emitting, and scattering media. Application to furnaces, high-temperature processing, pyrometry, insulation, and solar energy.
L. R. Glicksman, A. F. Sarofim

Power Systems

2.601J Design of Thermal Power Systems

(Same subject as 13.26J)
Prereq.: 2.005, 2.006, 2.51
G (Spring)
3-0-9 H-LEVEL Grad Credit

Design of thermal power system components and system optimization. Reviews gas dynamics and heat transfer. Design of axial and centrifugal compressors, and axial and radial inflow turbines, heat exchangers, evaporators, boilers, and condensers. Takes design project examples from the fields of space, electrical utilities, and marine power systems. Assumes knowledge of elementary heat transfer and simple power cycles.
L. R. Glicksman, A. D. Carmichael

2.615 Internal Combustion Engines

Prereq.: 2.005, 2.006
G (Spring)
3-0-9 H-LEVEL Grad Credit

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

2.648 Superconducting Magnets

Prereq.: 2.005, 2.51
G (Spring)
3-0-9 H-LEVEL Grad Credit

Focuses on one important engineering application of superconductors — generation of large-scale and intense magnetic fields. Review of electromagnetic theory; detailed treatment of magnet design and operational issues, e.g., "usable" superconductors, field and stress analyses, magnet instabilities, ac losses and mechanical disturbances, quench and protection, experimental techniques, cryogenics. New high-temperature superconductors for magnets — design and operational issues at high temperatures.
Y. Iwasa, E. S. Bobrov

Experimental Engineering

2.670 Mechanical Engineering Tools

Prereq.: —
U (IAP)
1-3-2 [P/D/F]

Introduces the fundamentals of machine tool and computer tool use. Students work with a variety of machine tools including the bandsaw, milling machine, and lathe. Instruction given on the use of the Athena network and Athena-based software packages including MATLAB, MAPLE, XESS, and CAD. Emphasis on problem solving, not programming or algorithmic development. Assignments are project-oriented relating to mechanical engineering topics. It is recommended that students take this subject in the first IAP after declaring the major in Mechanical Engineering.
D. P. Hart, K. N. Otto

2.671 Measurement and Instrumentation

Prereq.: 2.003, 8.02
U (Fall, Spring)
2-3-7 Institute LAB

Experimental techniques for observation and measurement of physical variables such as force, strain, temperature, flowrate, and acceleration. Emphasizes principles of transduction, measurement circuitry, spectral analysis, uncertainty analysis, computer-aided experimentation, and technical reporting. Typical laboratory experiments involve oscilloscopes, thermocouples, strain gages, digital recorders, lasers, etc. Basic material and lab objectives are developed in lectures. Six units may be applied to the General Institute Laboratory Requirement. Enrollment may be limited.
J. H. Lienhard, C. F. Dewey

2.672 Project Laboratory

Prereq.: 2.001, 2.003, 2.005, *2.006*, 2.671
U (Fall, Spring)
1-3-2 Institute LAB

Engineering laboratory subject for mechanical engineering juniors and seniors. Major emphasis on interplay between analytical and experimental methods in solution of research and development problems. Communication (written and oral) of results is also a strong component of the course. Groups of two or three students work together on three projects during the term. Limited enrollment.
W. Cheng, D. Hart

Design

2.72 Elements of Mechanical Design

Prereq.: 2.001, 2.007
U (Fall)
3-3-6

Examination and practice in the application of many mechanical design elements, including control components. Students working in groups will design, fabricate, and test prototype devices in response to requests from industrial sponsors. Topics: typical machine elements, power transmission elements, motors and prime movers, control elements, material selection, and assembly techniques. It is recommended that students not take this subject at the same time as 2.73. Elective unit distribution: Advanced disciplinary, 6; design, 6.
C. R. Peterson

2.721 Design for Production

Prereq.: 2.001, 2.007, 2.72, 2.008
U (Spring)
2-3-4

Intended primarily as a follow-up to 2.72. Students fabricate and test prototype devices that have been designed for real clients in 2.72. Simultaneously, these devices are redesigned for economical production in light of prototype experience and accompanying lecture material on manufacturing processes and materials.
C. R. Peterson

2.73 Design Projects
(Revised Units)

Prereq.: 2.007, 2.008
Acad Year 1996-97: U (Fall)
Acad Year 1997-98: **Not offered**
3-3-6

Practice in engineering design through term-long projects chosen to integrate significant portions of material covered in prerequisites. Emphasizes creative solutions to current engineering design problems, team work, and fabrication of prototypes. Often major involvement of a company in project definition and teaching. Lectures address the breadth of topics involved in engineering design from analytical techniques to human-machine interactions, economics, applied ethics, and patent laws.
W. C. Flowers, W. Seering

2.737 Mechatronics
(Revised Units)

Prereq.: 1.00, 2.010, 6.071, or equivalents; permission of instructor
U (Fall, Spring)
3-5-4

Introduction to designing mechatronic systems, which require integration of the mechanical and electrical engineering disciplines within a unified framework. Significant laboratory-based design experiences form subject's core. Final project. Topics include: low-level interfacing of software with hardware; use of C language and assembly language to implement real-time tasks; digital logic; analog interfacing and power amplifiers; measurement and sensing; electromagnetic and optical transducers; control of mechatronic systems. Limited enrollment. Elective unit distribution: Advanced disciplinary, 3, design 3, lab 6.
D. Trumper, K. Youcef-Toumi

2.739J Product Design and Development

(Same subject as 15.783J)
Prereq.: 15.760 or 15.761 or 2.731 or 2.73 or permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 15.783J.
S. D. Eppinger

2.74 Optimal Product Redesign

Prereq.: 2.007 or equivalent, access to PC or Macintosh
G (Fall)
3-0-6

Reverse engineering products, demonstrated with a consumer product case study redesigned in class through homework assignments. Lectures discuss: identifying objectives a product must satisfy; determining what the product has to satisfy the objectives; functional modeling of the product; morphological analysis; physical modeling for use in optimization studies using readily available computer tools; notions of performance and quality; designed experiments; prototyping solutions under real-world conditions.
K. Otto

2.744 Product Design

Prereq.: —
G (Spring)
3-1-8

Project-centered subject addressing transformation of ideas into successful new products which are properly matched to the user and the market. Students are asked to take a more complete view of a new product and to gain experience with designs judged on their aesthetics, ease of use, and sensitivities to the realities of the marketplace. Lectures on modern design process, design for quality, and design for manufacturability. Guest lectures and case studies from practitioners.
D. R. Wallace, W. C. Flowers

2.75 Precision Machine Design

Prereq.: 2.72 or permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

Intensive coverage of precision engineering theory, heuristics, and applications pertaining to the design of systems ranging from consumer products to machine tools. Topics covered include: economics, project management, and design philosophy; principles of accuracy, repeatability, and resolution; error budgeting; sensors; sensor mounting; systems design; bearings; actuators and transmissions. Emphasis on developing creative designs which are optimized by analytical techniques applied via spreadsheets. Many real-world examples are given, and classwork and tests are based on mini-design problems.
A. Slocum

Biomedical Engineering

(See also 2.277 and 2.907J.)

2.761J Principles of Medical Imaging

(Same subject as 22.56J, HST.561J)
Prereq.: Permission of instructor
G (Spring)
4-0-8 H-LEVEL Grad Credit

See description under subject 22.56J.
D. Cory, D. Rowell

2.763J Hyperthermia: Biology, Technology, and Cancer Therapy

(Same subject as HST.532J)
Prereq.: —
G (Spring)
4-1-7

Cellular and biological effects of hyperthermia; underlying mechanisms. Synergism with radiation and chemical injury. Heat generation and heat transfer in tissues and organs; bio-heat transfer modeling. Effects on tissue blood perfusion and oxygen transport; techniques of measurement. Ultrasonic and electromagnetic techniques for noninvasive regional and local hyperthermia. Tissue temperature measurement techniques. Effects on tumor and normal tissue in animals and man. Hyperthermia therapy planning. Clinical results. Thermal dosimetry. Research areas.
H. F. Bowman, Staff

2.781J Biomedical Instrumentation Electronics

(Same subject as HST.570J, 16.458J)
Prereq.: Permission of instructor
G (Summer)
6-6-6

See description under subject HST.570J.
D. Rowell, S. K. Burns

2.782J Design of Medical Devices and Implants

(Same subject as HST.524J)
Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject HST.524J.
I. Yannas, M. Spector

2.785J Mechanical Forces in Organ Development and Remodeling

(Same subject as 3.97J, HST.523J)
Prereq.: 3.091 or 5.11; 2.005 or 5.60; 7.012 or 7.013
G (Spring)
3-0-9 H-LEVEL Grad Credit

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

2.79J Biomaterials — Tissue Interactions

(Same subject as 3.96J, HST.522J)
Prereq.: 3.091 or 5.11; 2.005 or 5.60; 7.012 or 7.013
G (Fall)
3-0-9 H-LEVEL Grad Credit

Principles of materials science and cell biology underlying the design of medical implants and artificial organs. Methods for biomaterials surface characterization and analysis of protein adsorption on biomaterials. Molecular and cellular interactions with biomaterials are analyzed in terms of unit cell processes, such as matrix synthesis, degradation, and contraction. Mechanisms underlying tissue remodeling following implantation in various organs. Design of implants and prostheses based on control of biomaterials-tissue interactions. Comparative analysis of intact, biodegradable, and bioreplaceable implants by reference to case studies. Criteria for restoration of physiological function for tissues and organs.
I. V. Yannas, M. Spector

2.791J Quantitative Physiology: Cells and Tissues

(Subject meets with 6.021J, 2.794J, 6.521J, HST.541J)
Prereq.: 2.003 or 6.002 or 6.071 or 10.301; 8.02, 18.03
U (Fall)
5-2-5

For juniors and seniors. Meets with graduate subject 6.521J, but assignments differ. 4 Engineering Design Points. See description under subject 6.021J.
T. F. Weiss, D. M. Freeman

2.792J Quantitative Physiology: Organ Transport Systems

(Subject meets with 6.022J, 2.796J, 6.522J, HST.542J)
Prereq.: *2.791J*; 2.006 or 6.013
U (Spring)
4-2-6

See description under subject 6.022J.
R. G. Mark, R. D. Kamm

2.793J Quantitative Physiology: Sensory and Motor Systems

(Same subject as 6.023J, 16.401J, HST.543J)
Prereq.: 2.003 or 6.003 or 16.060
U (Spring)
3-2-7

See description under subject 6.023J.
L. S. Frishkopf, L. Young, C. Wall III, N. Hogan

2.794J Quantitative Physiology: Cells and Tissues

(Subject meets with 6.021J, 2.791J, 6.521J, HST.541J)
Prereq.: 2.003 or 6.002 or 6.071 or 10.301; 8.02, 18.03
G (Fall)
5-2-5

See description under subject 6.021J.
T. F. Weiss, D. M. Freeman

2.795J Fields, Forces, and Flows: Background for Physiology

(Same subject as 6.561J, HST.544J)
Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 6.561J.
A. J. Grodzinsky

2.796J Quantitative Physiology: Organ Transport Systems

(Subject meets with 6.022J, 2.792J, 6.522J, HST.542J)
Prereq.: 2.006 or 6.013; *6.021J*
G (Spring)
4-2-6

Meets with 6.022J. Requires the completion of more advanced home problems and/or an additional project. See description under subject 6.022J.
R. G. Mark, R. Kamm

Manufacturing

2.800 Tribology

Prereq.: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

Geometric, chemical, and physical characterization of surfaces. Various theories of friction and wear of metals, polymers, and ceramics. Special emphasis on delamination theory, discussion of erosion, boundary lubrication and solid-film lubrication. Rolling contact problems. Tribological problems in magnetic recording and electrical contacts. Monitoring and diagnosis of friction and wear. Case studies.
N. P. Suh, N. Saka

2.810 Fundamentals of Manufacturing Processes

Prereq.: 2.001, 2.006, 2.008, or equivalents
G (Fall)
3-3-6 H-LEVEL Grad Credit

Introduction to manufacturing processes including machining, injection molding, casting, composites, assembly, and others. Emphasis on the physics and the stochastic nature of the processes, and how these control the quality, rate, cost, and flexibility. Engineering analysis and probabilistic treatment include such topics as shrinkage and positioning errors, heat transfer, physical rate limits, information theory, and design for manufacture. Group project requires fabrication of a product using several processes, usually including CNC machining, injection molding, casting, and others. Discussion of new process development and potential competitive advantages.
T. G. Gutowski, J.-H. Chun

2.812 The Design and Control of Manufacturing Systems
(New)

Prereq.: 2.810 or permission of instructor
G (Spring)
3-6-3 H-LEVEL Grad Credit

Focuses on the history, development, and design of manufacturing systems. Project emphasis on designing a lean production system. Covers factory design, the design and formation of manufacturing cells (manned and automated), machine and setup design for manufacturing flexibility, and the use of information to control manufacturing systems. Relationships with area manufacturers have been established so that actual manufacturing system design problems are examined and solved in conjunction with the term project.
D. Cochran

2.82 Introduction to Manufacturing System Design
(New)

Prereq.: 2.008
U (Spring)
3-6-3 Institute LAB

Concentrates on the design of manufacturing systems. Goal is to design a lean manufacturing system. By designing an actual manufacturing system, students understand the engineering design principles necessary to enable the implementation and advancement of manufacturing system design. Design areas include factory design, the formation of manufacturing cells (manned and automated), machine and setup design for manufacturing flexibility, and the use of information to control manufacturing systems. Elective unit distribution: Advanced disciplinary 6, design 3, lab 3.
D. Cochran

2.822 Design and Manufacture with Composite Materials

Prereq.: 2.001, 2.006, 2.30, or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Theory and practice of how structures are designed and built out of composite materials. Principles introduced through case studies and laboratory demonstrations include: solid mechanics, anisotropy, differential geometry, consolidation and flow through porous media, forming, automation, assembly, and economics. Future developments in composite materials, markets, and processes discussed.
T. G. Gutowski

2.830 Control of Manufacturing Processes

Prereq.: 2.010 or 15.075 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Process control in manufacturing processes. Discrete system feedback control theory, empirical/adaptive modeling, and basic process physics understanding. A general framework for modeling and control of manufacturing processes is developed. Various existing forms of process control are studied, including off-line optimization, statistical process control, and real-time machine and process control. The control approach to process physics is examined in the context of specific manufacturing processes.
D. E. Hardt

2.851J System Optimization and Analysis for Manufacturing

(Same subject as 15.066J, 3.83J)
Prereq.: 18.02
G (Summer)
4-0-8 H-LEVEL Grad Credit

See description under subject 15.066J.
S. C. Graves, J. P. Clark

2.852 Manufacturing Systems Analysis

Prereq.: 6.041, permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Models of manufacturing systems, including transfer lines and flexible manufacturing systems. Calculation of performance measures, including throughput, in-process inventory, and meeting production commitments. Real-time control of scheduling. Effects of machine failure, set-ups, and other disruptions on system performance.
S. B. Gershwin

2.870 Total Quality Development

Prereq.: Permission of instructor required for undergraduates
G (Fall)
3-3-6 H-LEVEL Grad Credit

Total development process that begins with strategic needs and voice of customer and concludes with new product in production. Topics include House of Quality, Pugh Concept Selection, Extended and Enhanced QFD, robustness optimization (Taguchi), on-line QC, and holistic management. All topics are integrated into world-class concurrent engineering, an in-depth enhancement of basic TQM. Emphasis is on recent improvements in industrial practice.
D. Clausing

2.882 Principles of Axiomatic Design

Prereq.: 2.001, 2.006, 2.30, 2.005
G (Spring)
3-0-9 H-LEVEL Grad Credit

Introduction to design and design processes for products, processes, and systems; introduction to design axioms, corollaries, and theorems; mathematical representation of design; formulation of design matrix; analysis of functional independence; graphical representation of functional independence; measure of information content; application to process planning; case studies involving real industrial problems; robust design; optimization of designs. Design of Thinking Design Machine.
N. P. Suh

2.890J Proseminar in Manufacturing

(Same subject as 15.792J, 3.80J, 10.792J, 16.985J)
Prereq.: —
G (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit

See description under subject 15.792J.
Fall Term: *D. B. Rosenfield*
Spring Term: *J. Carroll*

2.891 Management for Engineers

Prereq.: —
G (Spring)
2-0-4

Provides an overview of management issues for graduate engineers. Topic is approached in terms of career options as engineering practitioner, manager, and entrepreneur. Specific topics include semantics, finance, TQM, starting a company, and people management. Through selected readings from texts and cases, focuses on the development of individual skills and management tools. Requires student participation and discussion, term paper. Limited to 25 graduate students.
A. V. d'Arbeloff, T. G. Gutowski

Polymers and Fibers

2.921J Deformation and Fracture of Polymers

(Same subject as 3.951J)
Prereq.: 2.001 or 3.11
G (Fall)
3-0-9 H-LEVEL Grad Credit

Linear and nonlinear viscoelasticity below and above T_g. Phenomenology of plastic deformation in crystalline, and glassy polymers, molecular theories for yielding, post yield extensions for intermediate and large strains, development of deformation textures, anisotropic yield conditions. Fracture in polymers, statistical damage accumulation. Crazing as a precursor to fracture, kinetics of nucleation of crazes, mechanics of craze extension, development and propagation of cracks. Fatigue in polymers under both static and cyclic loading.
I. V. Yannas

2.93J Engineers, Scientists, and Public Controversies

(Same subject as STS.012J)
Prereq.: —
U (Spring)
3-0-9 HASS

See description under subject STS.012J.
C. Weiner

Special Studies

2.942 Entrepreneurship

Prereq.: —
G (Spring)
4-0-5

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
T. G. Gutowski

2.943 Engineering Risk-Benefit Analysis

Prereq.: 18.02
G (Spring)
3-0-6 H-LEVEL Grad Credit

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
G. Apostolakis, A. W. Drake, A. R. Odoni

2.95J Real-World Ethics

(Same subject as TPP.09J)
Prereq.: —
U (Spring)
3-0-6 HASS

Prepares students to recognize ethical problems that commonly arise in the workplace, and to find, evaluate, use, and strengthen institutional supports for acting on ethical concerns. Lectures survey issues and practices in corporate and research contexts. In discussion sections, students develop ethics scenarios on issues of their choosing and explore them with representatives of corporations, universities, etc., at which students might work or study. Open to juniors and seniors. Others by permission.
C. Whitbeck, L. Bucciarelli

2.951 Engineering Internship

Prereq.: —
U (Fall, Spring, Summer)
0-6-0 [P/D/F]
Can be repeated for credit

2.952 Advanced Engineering Internship

Prereq.: 2.951
G (Fall, Spring, Summer)
0-6-0 [P/D/F]
Can be repeated for credit

Provides academic credit for undergraduate and graduate work assignments for Mechanical Engineering students participating in the Engineering Internship Program. Undergraduate participation is approximately six months over two summers of practical work in manufacturing, engineering, research and development at an industrial plant. Graduate participation by students admitted to the Department's graduate program consists of approximately seven months at industrial plant. Credit is awarded after evaluation and approval of the actual work performed.
P. Griffith

2.953J Research Ethics

(Same subject as 16.954J, TPP.41J)
Prereq.: —
G (Spring)
3-0-3

Examines the norms that govern research, the new policies for coping with changing conditions of research. Prepares students to address problems of research ethics and identify, evaluate, use, and strengthen institutional supports for acting on such ethical concerns. The core responsibilities for integrity of research results and for proper crediting of sources and collaborators are explored, together with the moral problems which, if poorly handled, are liable to create pressures to "cut corners." This is a half-term subject, taught in the first half of the term.
C. Whitbeck

2.954J Ethical Problems in Advanced Engineering and Science

(Same subject as TPP.42J)
Prereq.: 2.953J, 16.954J, TPP 41J, permission of instructor
G (Spring)
3-0-3

Examines moral problems in doctoral and postdoctoral engineering and science, and the scope and limits of the individual's or professor's opportunities and responsibility to address such problems. Topics such as responsibility for human subjects, for research animals, for safety, for "bugs," for public understanding of technology, for environmental effects, and issues such as rights of privacy (the new genetics, data banks), technology transfer, and academic-industrial collaboration. This is a half-term subject, taught in the second half of the term.
C. Whitbeck, N. Kiang

2.96 Management in Engineering

Prereq.: —
U (Fall)
3-0-9

Introduction of engineering management in variety of settings: 1) role of engineering and its relationship to other functions, 2) managerial tools and concepts used in engineering organizations, 3) practice in handling short- and long-term problems, 4) career strategy and development. Topics: financial principles, management of innovation, engineering project planning and control, human factors, career planning, patents, and technical strategy. Case method of instruction emphasizes participation in class discussion. Juniors, seniors, or graduate students. Elective unit distribution: Advanced disciplinary, 6; Design, 6. Engineering School-Wide Elective subject.
J.-H. Chun

2.97, 2.971 Independent Activities

Prereq.: —
U (IAP)
Units arranged
Can be repeated for credit

For undergraduates desiring to carry on independent or group studies during the January Independent Activities Period. Each student will carry on a program of his or her own choosing, either as an independent worker, or as a member of a team or class. Special lectures, seminars, and laboratory projects arranged when appropriate. Programs arranged on an individual basis in consultation with the instructor. Credit arranged with D. Rowell. 2.971 is graded P/D/F.

Graduate Seminars in Mechanical Engineering

Check with our Department graduate office prior to the beginning of each term for other proposed listings.

2.981 Low-Temperature Refrigeration

Prereq.: 2.005
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-3-6 H-LEVEL Grad Credit

Thermodynamic processes for producing low-temperature refrigeration. Problems of heat exchangers, insulation, and rectification. Applications of low-level refrigeration to liquefaction of helium and to application of superconductors. Laboratory projects on related topics according to individual interests.
J. L. Smith, Jr.

2.982 Microscale Heat Transfer

Prereq.: 2.51 or equivalent
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Sub-micron structures are the hallmark of electronic and biological systems. Microscale transport phenomena differ from those in the macroscopic realm if a geometric dimension, e.g., film thickness, becomes of the order of a phenomenological length-scale, e.g., radiation wavelength. This seminar introduces the breakdown limits of continuum analyses for radiation, conduction, convection, and phase change heat transfer. Participants present technical case studies in areas of their interest, such as electronic packaging or biological tissues.
E. Cravalho

2.990–2.991 Advanced Topics in Fluid and Thermal Sciences

Prereq.: 2.25, 2.451, 2.55
G (Spring)
2-0-4 H-LEVEL Grad Credit
Can be repeated for credit

Advanced subjects in transport phenomena taught for six weeks. Spring 1997: Microscale Laser Diagnostics and Processing. Principles of laser-material interactions: electronic structures of materials and light absorption/emission by gas molecules, small particles, and solids. Microscale energy transfer in laser diagnostics and processing. Optical detection and imaging. Applications of laser spectroscopy in combustion, fluid flow, heat transfer, and bioengineering. Laser microfabrication. Extremes of laser technology.
M. Johnson, T. Q. Qiu

2.993–2.995 Special Topics in Mechanical Engineering

Prereq.: —
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit

For undergraduates desiring to carry on substantial projects of own choice, under faculty supervision, in mechanical engineering. Work may be of experimental, theoretical, or design nature. Projects may be arranged individually in most fields of department interest, i.e., in mechanics and materials, thermal and fluid sciences, systems and design, and biomedical engineering.
Coordinator: D. Rowell.

2.996–2.998 Advanced Topics in Mechanical Engineering

Prereq.: —
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Assigned reading and special problems or research in special areas, either theoretical or experimental, or design. Arranged on individual basis with instructor in the following areas: mechanics and materials, thermal and fluid sciences, systems and design, and biomedical engineering. Coordinator: A. A. Sonin.

2.999 Engineer's Degree Thesis Proposal Preparation

Prereq.: —
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

For students who must do additional work to convert an S.M. Thesis to an M.E. Thesis, or for students who do an M.E. Thesis after having received an S.M. degree.
A. A. Sonin

2.ThG Graduate Thesis

Prereq.: —
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Program of graduate research, leading to the writing of an S.M., Ph.D., or Sc.D. thesis; to be arranged by the student and an appropriate MIT faculty member.
Consult Department Headquarters.

2.THU Undergraduate Independent Study or Thesis

Prereq.: —
U (Fall, Spring, Summer)
Units arranged
Can be repeated for credit

Individual self-motivated study, research, or design project under faculty supervision.
Departmental program requirement: Minimum of 6 units.
D. Rowell

Course 3

Materials Science and Engineering

For degree requirements, see listing in Chapter VII under the School of Engineering.

3.UR Undergraduate Research

Prereq.: —
U (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit

3.URG Undergraduate Research

Prereq.: —
U (Fall, Spring, Summer)
Units arranged
Can be repeated for credit

Extended participation in work of a research group. Independent study of literature, direct involvement in group's research (commensurate with student skills), and project work under an individual faculty member. See UROP coordinator for registration procedures.
D. K. Roylance

3.ThU Undergraduate Thesis

Prereq.: —
U (Fall, Spring, Summer)
Units arranged
Can be repeated for credit

Program of undergraduate research, leading to the writing of an S.B. thesis; to be arranged by the student and an appropriate MIT faculty member.
Consult D. K. Roylance.

3.00 Thermodynamics of Materials

Prereq.: 18.02
U (Fall)
4-0-8 REST

Essential features of first, second, and third laws of thermodynamics and their application to materials. Statistical interpretation of entropy. Experimental techniques used to measure thermodynamic functions. Introduces phase diagrams, phase rule, and thermodynamics of solutions. Thermochemistry of homogeneous and heterogeneous reactions.
G. Ceder

3.01 Physical Chemistry of Materials

Prereq.: 3.00 or 5.60 or 2.40 or 10.213
U (Spring)
4-0-8

Reactions involving pure condensed phases and gaseous phase, behavior of solutions, free energy-composition and phase diagrams of binary and ternary systems, reaction equilibria in systems containing components in condensed solution. Electrochemistry, corrosion, Gibbs phase rule, chemical kinetics, elementary mechanisms, reaction rate constant, activation energy, surface tension.
D. V. Ragone

3.03 Chemical Metallurgy

Prereq.: 3.185
U (Spring)
3-0-9

Thermodynamics and kinetic principles along with aspects of process control and economics involved in extraction and processing of metals. Unit operations and processes. Generalizing operations in terms of gas-liquid, solid-solid, gas-solid, liquid-liquid, and gas-solid-liquid reactions. Electrochemical processes. Designing energy-efficient and environmentally sound processes.
U. B. Pal

3.035, 3.036, 3.037 Special Problems in Materials Science and Engineering

Prereq.: Permission of instructor
U (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit

3.038, 3.039, 3.04 Special Problems in Materials Science and Engineering

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

For undergraduates desiring to carry on projects of their own choosing, which may be experimental, theoretical, or of a design nature. Also for undergraduate studies arranged by students or staff, which may consist of seminars, assigned reading, or laboratory projects. See UROP Coordinator for registration procedures.
D. K. Roylance

3.041 Undergraduate Research Seminar

Prereq.: —
U (Spring)
0-3-0

Basic skills for conducting research in materials science and engineering. Includes library resources, how to plan experiments, laboratory safety, data analysis, oral presentations and technical writing of proposals and reports. Intended for the sophomore year, open to freshmen.
T. W. Eagar, D. K. Roylance

3.05 Computer Models of Physical and Engineering Systems

Prereq.: 18.03 or 18.034, 1.00
U (Spring)
3-1-8

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
F. Peña-Mora

3.062 Polymer Chemistry

Prereq.: 3.091 or 5.11
U (Fall)
4-0-8

Preparation of polymeric materials and their characterization. Topics: fundamentals of chain and step growth polymerization, chemistry of organic radicals and ions, synthesis-structure-property relationships, and use of modern techniques for determination of polymer composition, molecular weight, and microstructure.
M. F. Rubner

3.063 Polymer Physics

Prereq.: 3.062, 3.00
U (Spring)
4-0-8

Principles underlying the physics and physical chemistry of polymers in solution and in the solid state. Topics include conformation and molecular dimensions of polymer chains; thermodynamics of polymer solutions; an examination of the glassy, crystalline, and rubbery elastic states of polymers; kinetics and thermodynamics of crystallization; liquid crystallinity in polymers; thermodynamics of rubber elasticity. The electrical, optical, transport, and mechanical properties of polymers are analyzed with respect to the above topics.
E. L. Thomas

3.064 Polymer Engineering

Prereq.: 3.11, 3.185
U (Spring)
3-0-9

Overview of engineering analysis and design techniques for synthetic polymers. Treatment of materials selection, mechanical characterization, and processing in design of load-bearing and environment-compatible structures.
F. J. McGarry, D. K. Roylance

3.069 Ceramics Processing

Prereq.: 3.185
U (Spring)
3-0-9

In-depth study of the unit operations in processing technical ceramics and the effect of these operations on the properties of the sintered material. Topics include powder production and conditioning, drying, forming, sintering, and microstructure development. Relevant aspects of transport phenomena, colloid science, and chemistry are discussed, as well as contemporary issues in ceramic composite processing. Case studies involving both electronic and structural ceramics are reviewed.
M. J. Cima

3.07 Introduction to Ceramics

Prereq.: 3.01, 3.13
U (Fall)
4-0-8

Discusses structure-property relationships in ceramic materials. Includes hierarchy of structures from the atomic to microstructural levels. Defects, atom mobility, solid-state electrochemical processes, phase equilibria, and phase transformations are discussed in the context of controlling properties for structural and electronic applications of ceramics. Numerous examples from current technology.
Y.-M. Chiang

3.070J Materials for Nuclear Applications

(Subject meets with 22.70J, 3.711J, 22.070J)
Prereq.: 3.091
U (Spring)
3-0-9

See description under subject 22.70J.
K. C. Russell

3.08J Industrial Competition in the US and Asia

(Same subject as 21H.541J, TPP.03J)
Prereq.: —
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: U (Spring)
2-0-7 HASS

Examines causes of economic efficiency and international competitiveness in the US and Asia, considering relative importance of technological, economical, social, and historical factors. Countries discussed include modern China (mainland, Taiwan, and Hong Kong), South Korea, and Japan. Topics include costs of production, product quality, organizational structures, labor relations, and the educational system. Case studies of selected industries such as automotive, steel, electronics, computers, and biotechnology.
J. P. Clark, P. C. Perdue

3.081 Materials Structure Laboratory

Prereq.: 3.13 or permission of instructor
U (Fall, Spring)
1-6-5 Institute LAB

Structure, structural transitions, and their influence on materials properties are examined by classical characterization methods (optical and electron microscopy, X-ray diffraction, UV and IR spectroscopy, TGA, DSC) and by more recently developed tools (AFM, Auger spectroscopy, molecular simulation). Investigations address four central themes: electronic and chemical structure, order and disorder, surfaces and interfaces, nucleation and growth. Unknown materials determination and materials design for the environment.
Fall Term: *A. M. Mayes*
Spring Term: *L. W. Hobbs*

3.082 Materials Processing Laboratory

Prereq.: 3.01, 3.081, 3.13
U (Fall, Spring)
1-6-5

A unified laboratory teaching students how to tailor the properties and performance of a material by modifications in its composition and microstructure through synthesis and processing. Students process materials from different classes (metals, ceramics, polymers, and electronic materials). Design is an integral part of this subject, which consists of two six-week project modules. Examples include solidification processing, powder processing, and thin-film processing of materials for magnetic, electronic, optical, and structural applications.
Y.-M. Chiang, D. C. Dunand, J. S. Haggerty, M. F. Rubner, C. E. Scott

3.091 Introduction to Solid-State Chemistry

Prereq.: —
U (Fall, Spring)
5-0-7 CHEMISTRY

Introduction to the basic principles of chemistry and their application to the solid state. Development of relationships between electronic structure of elements, chemical bonding, and crystal structure. Characterization of atomic and molecular arrangements in crystalline and amorphous solids. Chemical kinetics. Phase diagrams. Examples from contemporary industrial pratice (including the environmental impacts of processes and products) and from emerging technologies, e.g., biomaterials.
Fall Term: *D. R. Sadoway*
Spring Term: *R. M. Latanision*

3.092 Perspectives in Materials Science

Prereq.: —
U (Spring)
2-0-4 [P/D/F]

Surveys, in some depth, materials science and its applications at levels suitable for those with no prior experience in the field. Lectures by MIT staff and guests form a series of integrated seminars on important aspects of the field.
A. F. Witt

3.093 Hotter, Faster, Stronger, Cheaper: Materials at the Frontiers of Engineering

Prereq.: —
U (IAP)
1-0-2 [P/D/F]

Illustrates the physical and economic limits to performance of engineering systems imposed by properties and costs of currently available materials in a series of case-study lectures by MIT staff and guests. Explores how and why materials behave as they do, as well as prospects and opportunities for the development of new materials. Suitable for those with no prior experience in materials science.
J. P. Clark

3.10 Chemical Physics of Materials

Prereq.: 3.091 or 5.11; 8.02, 18.03
U (Spring)
4-0-8 REST

Introduction to the physics of the chemical bond in molecules and solids; electrons and energy bands in solids; electrical, optical, magnetic, and thermal properties.
E. A. Fitzgerald, J. D. Livingston

3.11 Mechanics of Materials

Prereq.: 3.01, 3.13
U (Spring)
4-0-8

Overview of mechanical properties of ceramics, metals, and polymers, emphasizing the role of processing and microstructure in controlling these properties. Introduction to continuum concepts of stress and strain, and design of engineering structures from a materials point of view.
S. Suresh, D. K. Roylance

3.13 Structure of Materials

Prereq.: 3.091 or 5.11; 8.02, 18.02
U (Fall)
4-0-8 REST

Provides fundamental basis for understanding structure and its relationship to physical properties. Symmetry theory for the description of the atomic and molecular arrangements in crystals. Principles of space groups and use of *International Tables for Crystallography* for specifying crystal structure. Point, line, and planar imperfections in ordered media. Quantitative description of noncrystalline materials. Liquid crystals. Fractals. Structural hierarchies. Influence of processing on microstructure; structure-property relations.
S. M. Allen, E. L. Thomas

3.14 Physical Metallurgy

Prereq.: 3.01; 3.11; 3.13
U (Fall)
3-0-9

Treats phase transformation and strengthening mechanisms in metals and alloys. Also provides an introduction to processing, microstructures, and properties of alloy systems of major engineering significance.
A. Mortensen

3.15 Electrical, Optical, and Magnetic Materials and Devices

Prereq.: 3.10
U (Fall)
4-0-8

Explores the relationships which exist between the performance of electrical, optical, and magnetic devices and the microstructural characteristics of the materials from which they are constructed. Features a device-motivated approach which places strong emphasis on emerging technologies. Device applications of physical phenomena are considered, including electrical conductivity and doping, photodetection, photoluminescence and electroluminescence, light amplification, nonlinear optics and optical switching, ferroelectricity, and ferromagnetism.
K. D. Kolenbrander

3.155J Microelectronics Processing Technology

(Same subject as 6.152J, 10.480J)
Prereq.: Permission of instructor
U (Fall, Spring)
3-4-5

See description under subject 6.152J.
L. C. Kimerling, C. V. Thompson, H. H. Sawin, M. A. Schmidt, C. G. Sodini, K. K. Gleason

3.172 Inventions and Patents

Prereq.: 14.02
U (Fall)
3-0-6

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
R. H. Rines

3.185 Transport Phenomena in Materials Engineering

Prereq.: 3.01, 18.03
U (Fall)
4-0-8

Definition of viscosity, simple overall mechanical energy balances, elements of laminar flow and turbulent flow. Thermal conductivity, steady and unsteady conduction problems, forced and natural convection, heat transfer coefficient, and radiative heat transfer. Definition of binary diffusivity, convection mass transfer, and mass transfer coefficient. Illustrative examples given throughout, chosen from the materials processing field.
M. C. Flemings

3.ThG Graduate Thesis

Prereq.: —
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Program of graduate research, leading to the writing of an S.M., Ph.D., or Sc.D. thesis; to be arranged by the student and an appropriate MIT faculty member.
Consult L. W. Hobbs in Room 8-303.

3.20 Thermodynamics of Materials

Prereq.: 3.00, 3.01, or permission of instructor
G (Fall)
4-0-8 H-LEVEL Grad Credit

Offers advanced treatment of thermodynamic properties of inorganic materials, including introductory statistical thermodynamics and surface thermodynamics. Applies laws of thermodynamics to chemical behavior of elements, compounds, and solutions. Discusses heterogeneous equilibria, chemical reactions, and thermodynamics of interfaces and structural defects.
K. C. Russell

3.21 Kinetic Processes in Materials

Prereq.: 3.00, 3.01, 3.185, or permission of instructor
G (Spring)
4-0-8 H-LEVEL Grad Credit

Presents unified treatment of kinetics from phenomenological and atomistic viewpoints. Covers diffusion in metals and non-metals, chemical kinetics, and kinetics of phase transformations, including nucleation, growth, coarsening, and spinodal decomposition. Also includes non-catalytic gas-solid reactions and oxidation of metals and alloys.
S. M Allen, R. W. Balluffi

3.271 Structure of Materials

Prereq.: 18.03, 3.10
G (Spring)
4-0-8 H-LEVEL Grad Credit

Quantitative description of atomic arrangements in selected metals, oxides, and silicates important in materials science. Interprets structures in terms of coordination polyhedra and packing. Relationships between structures: polymorphism, polytypism, and derivative structures. Describes diffraction using Fourier transforms and series. Determines structure through diffraction effects: the phase problem, Patterson function, and direct methods for phase determination.
B. J. Wuensch

3.29 Special Problems in Materials Science

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

3.291 Special Problems in Materials Science

Prereq.: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Advanced work in the field for qualified students. Lectures, conferences, assigned readings, or supervised laboratory work.
R. M. Rose

3.30 Electron Microscopy: Image Interpretation

Prereq.: 3.081, 3.13
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-2-7 H-LEVEL Grad Credit

Derives relationship between detail in transmission electron microscopy images and internal structure of an object to the atomic level. Fourier theory of diffraction. Lens action, aberrations, and transfer functions. Elastic and inelastic interaction of electrons with atoms. Kinematical and dynamical theories of electron diffraction. Phase object approximations and high-resolution imaging methods. Imaging of defects with displacement and replacement fields. Laboratory sessions. Alternate years.
L. W. Hobbs

3.31 Phase Transformations

Prereq.: 3.20, 3.21
G (Spring)
3-0-9 H-LEVEL Grad Credit

Advanced treatment of phase transformations in solids. Homogeneous and heterogeneous nucleation. Theories of thermally activated growth processes and morphological stability. Transformation by spinodal decomposition and continuous ordering. Transformation mechanisms in systems with multicritical points. Eutectoidal transformations and cellular precipitation. Crystallographic theory and mechanisms of martensitic transformations.
R. M. Rose

3.320 Atomistic Computer Modeling of Materials

Prereq.: 3.20, 3.13, or permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Atomistic computer modeling as a tool to solve problems in materials science and engineering. Deterministic and stochastic methods. Monte Carlo and molecular dynamics. Energy models (classical and quantum-mechanical). Free energy computation. Phase transformations. Metastability. Order-disorder transformations. Defect properties. Transport properties. Emphasis on solving relevant problems in a variety of materials classes.
G. Ceder

3.33 Defects in Crystals

Prereq.: 3.13, 3.14
G (Spring)
3-0-9 H-LEVEL Grad Credit

Unified treatment of point, line, and planar defects in crystals. Point defects include vacancies, self-interstitials, and solute atoms. Line defects include dislocations. Planar defects include stacking faults, small- and large-angle grain boundaries, and interphase boundaries. Discusses geometrical structure and physical properties such as stress fields, energies, and mobilities. Treats interactions between defects including point defect clustering, point defect-dislocation pinning, dislocation climb, and grain boundaries as point defect sources/sinks.
R. W. Balluffi

3.34 High-Temperature Materials

Prereq.: 3.11 or 3.14 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Covers the relationship between deformation mechanisms and microstructure for materials used at elevated temperature. Mechanisms: diffusional creep, dislocation creep, grain-boundary sliding and superplasticity, fatigue, fracture, environmental effects. Microstructure: metals (iron-, cobalt-, nickel-, refractory- and intermetallic alloys), ceramics, composites (metal-, ceramic- and carbon-matrix, coated materials).
D. C. Dunand

3.35 Fracture and Fatigue

Prereq.: 2.30 or 3.11 or equivalent
G (Fall)
3-0-9 H-LEVEL Grad Credit

Linear elastic and elastic plastic fracture mechanics. Experimental methods. Microstructural effects on fracture in metals, ceramics, polymers, electronic materials, and composites. Toughening mechanisms. Crack growth resistance and creep fracture. Interface fracture mechanics. Fatigue damage and dislocation substructures in single crystals. Stress- and strain-life approach to fatigue. Fatigue crack growth models and mechanisms. Variable amplitude fatigue. Corrosion fatigue. Case studies. Co-taught with Professor A. G. Evans, Harvard University.
S. Suresh

3.36J Welding Engineering

(Same subject as 13.17J)
Prereq.: 13.15
G (Spring)
3-0-6 H-LEVEL Grad Credit

See description under subject 13.17J.
K. Masubuchi

3.37 Welding and Joining Processes

Prereq.: —
G (Fall, IAP, Spring, Summer)
3-0-3 H-LEVEL Grad Credit

Discusses a wide variety of processes and materials from the viewpoint of their fundamental physical and chemical properties. Specific topics: cold welding, adhesive bonding, diffusion bonding, soldering, brazing, flames, arcs, high-energy density heat sources, solidification, cracking resistance, shielding methods, and electric contacts. Emphasis on underlying science of a given process rather than a detailed description of the technique or equipment.
T. W. Eagar

3.39 Mechanical Properties of Materials
(Revised Content)

Prereq.: 2.30; 3.11 or 22.71J
G (Fall)
3-0-9 H-LEVEL Grad Credit

Reviews elasticity theory. Elements of continuum plasticity and dislocation plasticity. Strengthening mechanisms in metals. Basics of viscoelasticity and creep. Applications of principles in linear elastic fracture mechanics to brittle fracture and to fatigue crack propagation. Micromechanisms of static and cyclic fracture. Discusses case studies and reviews current research in the mechanical behavior of structural and device materials with examples in each class of materials: metals, ceramics, polymers, thin films, and composites.
D. C. Dunand, S. Suresh

3.40J Physical Metallurgy

(Same subject as 22.71J)
Prereq.: 3.14 or 3.711J
G (Fall)
3-0-9 H-LEVEL Grad Credit

Discusses structure-property relationships in metallic alloys selected to illustrate some basic concepts of physical metallurgy and alloy design. Considers mostly mechanical properties. Also considers structural features: structural stability, grain size, interstitial and substitutional solutes, precipitates, second-phase particles, eutectics and eutectoids, and composites.
R. W. Balluffi

3.41 Physics and Chemistry of Materials

Prereq.: 8.03, 18.03
G (Fall)
4-0-8 H-LEVEL Grad Credit

Quantum physics and chemistry and statistics of electrons, atoms, molecules, and solids. Electron structure of crystalline and amorphous materials, defects, surfaces, and interfaces. Transport in metals, semiconductors, and insulators — ideal and defective. Introduction to junction theory. Optical and dielectric phenomena — absorption, emission, refraction. Magnetic phenomena — dia-, para-, and ferro-magnetism. Superconductivity. Implications for properties of interest.
E. A. Fitzgerald

3.42 Electronic Materials Design

Prereq.: 3.41
G (Spring)
3-0-9 H-LEVEL Grad Credit

Extensive and intensive examination of structure (crystalline, electronic, defect, and microstructure)-processing-property correlations for a wide range of materials including metals, semiconductors, dielectrics, optical, magnetic, and superconducting materials. Emphasis on materials design in relation to fundamental device characteristics.
K. D. Kolenbrander, H. L. Tuller

3.43 Electronic Materials and Devices

Prereq.: 3.20, 3.42
G (Fall)
3-0-9 H-LEVEL Grad Credit

Detailed examination of the principal electrical, optical, and magnetic devices, e.g., p-n, Schottky, MOS and heterojunctions, quantum wells, lasers, wave guides, detectors, solar cells, magnetic memory devices, etc. Focus on materials selection, optimization and integration. Discussion of new materials needs and alternative processing routes.
H. L. Tuller

3.44 Electronic Materials Processing

Prereq.: 3.20, 3.21
G (Fall)
3-0-9 H-LEVEL Grad Credit

Processing of electronic materials for device and circuit applications. Detailed discussion of techniques and theory for growth of device-quality crystals. Processes for integrated circuit fabrication including oxidation, junction formation, and metallization. Emphasis on relationships among processing, structure, and properties. Examples taken from materials processing for applications in VLSI, optoelectronics, and multi-layer integration.
C. V. Thompson

3.45 Magnetic Materials

Prereq.: 3.41
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Magnetization phenomena, origin of magnetism in a material, magnetic domains and domain walls, magnetic anisotropy, reversible and irreversible magnetization processes. Special topics: ferromagnetism of thin films and fine particles, magnetic recording, magnetic circuits, amorphous magnetic materials. Alternate years.
R. C. O'Handley

3.46 Optical and Optoelectronic Materials

Prereq.: 3.42 or equivalent
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Optical and optoelectronic properties of semiconductors, ceramics, and polymers. Electronic structure, refractive index, electroluminescence, Kerr and Faraday effects, and laser phenomena. Materials design and processing for lasers, waveguides, modulators, switches, and optoelectronic integrated circuits. Alternate years.
L. C. Kimerling

3.471 Advanced Topics on the Physics and Chemistry of Materials

Prereq.: 3.41 or equivalent or permission of instructor
G (Spring)
4-0-8 H-LEVEL Grad Credit

Topics on the physics and chemistry of materials not covered in the core subject of 3.41 including: molecular and crystal symmetry group theory; ligand-field theory; applications of quantum chemistry to the electronic structures of magnetic materials, high-Tc superconductors and organic electronic materials; surface physics and chemistry; chemisorption and catalysis. Topics tailored to students' research interests.
K. H. Johnson

3.48 Statistical Physics of Materials

Prereq.: 3.20
G (Spring)
3-0-9 H-LEVEL Grad Credit

Reviews basic classical and quantum statistical mechanics. Introduces Boltzmann transport theory. Discusses Ising and Heisenberg soluble models with application to order-disorder in alloys and magnetic materials; structural phase transformations by Landau, renormalization-group and Jahn-Teller theories, with application to defect statistics, melting, and polymer statistics; and electronic phase transformations in ferromagnetic, antiferromagnetic, ferroelectric, and superconducting materials. Alternate years.
K. H. Johnson

3.49 Special Problems in Electronic Materials

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

3.491 Special Problems in Electronic Materials

Prereq.: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Advanced work for qualified students. Lectures, conferences, assigned readings, or supervised laboratory work.
H. L. Tuller

3.50 High-Temperature Physical Chemistry of Materials

Prereq.: 3.01
G (Fall)
3-0-9 H-LEVEL Grad Credit

Application of physicochemical principles to study the nature of solids, liquids, and gases and heterogeneous reactions between these phases at elevated temperatures. Transport in multi-component solids and liquids. Systems of interest include liquid metals, semiconductors, and other multicomponent solid and liquid oxides.
U. B. Pal

3.51 Materials and the Environment

Prereq.: 3.205 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Industrial ecology of materials, i.e., how they are extracted, refined, and recycled. Considers the environmental impacts of the associated materials processing operations, pollution control and waste treatment efforts, and recycling options. Provides an intellectual platform for green design. Energy audits, environmental audits, and cost assessments.
D. R. Sadoway

3.52J Materials Processing

(Same subject as 10.581J)
Prereq.: 3.01, 3.185, or equivalents
G (Spring)
3-0-6 H-LEVEL Grad Credit

Fundamentals of thermal, powder, and vapor processing; solidification, sintering, deformation processing, and composite materials processing. Particular attention paid to structural evolution during processing, and resulting material properties and performance.
A. Mortensen, K. F. Jensen, M. C. Flemings

3.53 Electrochemical Processing of Materials

Prereq.: 3.185
G (Spring)
3-0-6 H-LEVEL Grad Credit

Principles of electrochemistry: thermodynamics and kinetics of electrode processes, thermodynamic and transport properties of aqueous and nonaqueous electrolytes. Electrolytic processing: electrowinning, electrorefining, electroplating, electrosynthesis, electroslag remelting.
D. R. Sadoway

3.54J Corrosion: The Environmental Degradation of Materials

(Same subject as 22.72J)
Prereq.: 3.00
G (Fall)
3-0-6 H-LEVEL Grad Credit

Applies thermodynamics and kinetics of electrode reactions to aqueous corrosion of metals and alloys. Forms of corrosion and corrosion testing. Methods of corrosion control including alloy selection, water chemistry, design rules, anodic and cathodic protection, and coatings. Extension to environmental degradation of ceramics and polymers. Discusses materials degradation problems in marine environments, oil and gas production, energy conversion and generation systems.
R. G. Ballinger

3.541 Oxidation and Corrosion of Materials at Elevated Temperatures

Prereq.: 3.20, 3.21
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-6 H-LEVEL Grad Credit

Application of fundamental principles of thermodynamics and kinetics to determination of the mechanisms of the oxidation and corrosion of materials at elevated temperatures. Relationship of oxidation theory to design of alloys, and of coating materials for protection against oxidation. Discussions of high-temperature oxidation and corrosion problems that occur in systems for the conversion and utilization of energy, and in petrochemical and metallurgical industries. Alternate years.
L. W. Hobbs

3.55 Macroscopic Transport in Materials Processing

Prereq.: 18.03
G (Spring)
3-0-9 H-LEVEL Grad Credit

Principles of mathematical and physical modeling of primary metals processing, welding, rapid solidification, and the processing of electronic materials. The transport equations as building blocks of mathematical models. Similarity criteria in building of physical models. Synthesis of an optimal modeling approach, involving mathematical models, physical models, and pilot plants.
C. E. Scott

3.56 Engineering Systems Analysis

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

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
R. de Neufville, F. Field

3.560J Industrial Ecology

(Same subject as TPP.123J, 1.814J)
Prereq.: TPP.11 or 3.56
G (Spring)
3-0-6 H-LEVEL Grad Credit

See description under subject TPP.123J.
J. Clark, F. Field, R. de Neufville

3.563J Strategic Analysis for Environmental Policy Planning, Design, and Implementation

(Same subject as 1.141J, 6.688J, 11.385J, 22.822J, TPP.121J)
Prereq.: 1.146 or 2.192 or 3.56 or 13.62 or 16.861 or TPP.21 or 11.200 or 11.205
G (Spring)
3-0-6 H-LEVEL Grad Credit

See description under subject 1.141J.
D. H. Marks, R. de Neufville, J. Clark, R. Gakenheimer, M. W. Golay, D. Sadoway, R. D. Tabors

3.566 Entrepreneurship

Prereq.: —
G (Spring)
4-0-5

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
T. G. Gutowski

3.577 Engineering Risk-Benefit Analysis

Prereq.: 18.02
G (Spring)
3-0-6 H-LEVEL Grad Credit

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
G. Apostolakis, A. W. Drake, A. R. Odoni

3.595 Special Problems in Materials Engineering

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

3.596 Special Problems in Materials Engineering

Prereq.: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Advanced work in the field for qualified students. Lectures, conferences, assigned readings, or supervised laboratory work.
R. M. Latanision

3.60 Symmetry, Structure, and Tensor Properties of Materials

Prereq.: 3.07
G (Fall)
4-0-8 H-LEVEL Grad Credit

Derivation of symmetry theory; lattices, point groups, space groups and their properties. Use of symmetry in tensor representation of crystal properties, including anisotropy, representation surfaces, as well as applications to piezo-electricity and elasticity. Quantative description of atomic arrangements in selected metals, oxides, and silicates important in materials science. Interprets structure in terms of coordination polyhedra and packing, and examines relations between structures: polymorphism, polytypism, and derivative structure.
B. J. Wuensch

3.62 Defect Thermodynamics and Solid State Electrochemistry

Prereq.: 3.20
G (Fall)
2-0-4 H-LEVEL Grad Credit

The defect solid state is analyzed after a short review of the perfect solid state. Equilibrium and nonequilibrium thermodynamics of point defects are applied to bulk and interfacial problems, conduction and diffusion, solid-state reactions, and heterogeneous catalysis. Materials examples include fast ion conductors and high temperature superconductors. Special attention is paid to experimental electrochemical methods and important electrochemical applications (batteries, fuel cells, photoelectrochemical elements, and sensors). Half-term subject taught second half of term.
J. Maier

3.63 Ceramic Processes

Prereq.: 3.07, 3.20
G (Fall)
3-0-6 H-LEVEL Grad Credit

Presents quantitative treatment of unit operations in powder processing-powder preparation, fabrication, and firing. Discusses glass processing-homogenization during melting: relationship to mixing theory-glass forming. Also covers growth of crystals, thermodynamics, transport processes, and kinetics in relation to structures developed.
M. J. Cima

3.64 Special Problems in Ceramics

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

3.641 Special Problems in Ceramics

Prereq.: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Explores advanced work in this field. Lectures, conferences, assigned readings, and laboratory work.
B. J. Wuensch

3.691–3.699 Teaching Materials Science and Engineering

Prereq.: —
G (Fall, Spring)
Units arranged
Can be repeated for credit

Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview. (Enrollment limited by availability of suitable teaching assignments.)
K. C. Russell

3.70 Special Problems in Metallurgy

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

3.701 Special Problems in Metallurgy

Prereq.: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Minor investigation in one of the special branches of metallurgy. (Open only to students properly qualified in the special field.)
K. C. Russell

3.711J Materials for Nuclear Applications

(Subject meets with 22.70J, 3.070J, 22.070J)
Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 22.70J.
K. C. Russell

3.80J Proseminar in Manufacturing

(Same subject as 15.792J, 2.890J, 10.792J, 16.985J)
Prereq.: —
G (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit

See description under subject 15.792J.
D. B. Rosenfield, J. S. Carroll

3.81J Engineering Probability and Statistics

(Same subject as 6.430J, 15.064J)
Prereq.: 18.02
G (Summer)
4-0-8 H-LEVEL Grad Credit

See description under subject 6.430J.
A. W. Drake

3.83J System Optimization and Analysis for Manufacturing

(Same subject as 15.066J, 2.851J)
Prereq.: 18.02
G (Summer)
4-0-8 H-LEVEL Grad Credit

See description under subject 15.066J.
S. C. Graves, J. P. Clark

3.891 Structure and Properties of Materials

Prereq.: 8.03, 18.03
G (Summer)
3-0-9 H-LEVEL Grad Credit

Structure-properties relationships in materials. Electrons in atoms and molecules, metallic, covalent, and ionic bonding and its relationship to structure and properties of crystalline and non-crystalline solids, structure and its determination in crystalline and non-crystalline solids, the defect solid state: point, line, areal, and volume defects. Mechanical electronic, magnetic, and phototonic properties, their measurement, and their relationship to structure.
K. C. Russell