### 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*

### 3.90J Fracture of Structural Materials

(Same subject as 1.591J, 13.16J)
Prereq.: 2.30 or 3.11 or 13.15
G (Fall)
3-0-6 H-LEVEL Grad Credit

Analyzes criteria for crack initiation and propagation leading to structural failure. Studies fracture mechanics starting with Griffith theory for ideally brittle materials, through plane strain fracture toughness phenomena. Effects of geometry, rate, environment, fatigue, temperature, composition, and microstructure. Fracture behavior of welded metals, heat-affected zone. Relation to dislocation mechanics. Significance of fracture surface morphology. Metals, polymers, fiber-reinforced composites. Emphasizes current research in field.
*F. J. McGarry, K. Masubuchi*

### 3.901 Special Problems in Polymer Science and Engineering

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

### 3.902 Special Problems in Polymer Science and 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. Lectures, conferences, assigned readings, and laboratory work.
*M. F. Rubner*

### 3.903J Student Seminar in Polymer Science and Technology

(Same subject as 10.960J)
Prereq.: —
G (Fall, Spring)
2-0-0 [P/D/F]
Can be repeated for credit

See description under subject 10.960J.
*R. E. Cohen, M. F. Rubner, G. C. Rutledge, P. T. Hammond, E. W. Merrill*

### 3.91J Mechanical Behavior of Plastics

(Same subject as 1.593J)
Prereq.: 3.064
G (Spring)
3-2-4 H-LEVEL Grad Credit

Relation among chemical composition, physical structure, and mechanical behavior of plastics or synthetic high polymers. Study of types of polymers; fundamentals of viscoelastic phenomena such as creep, stress relaxation, stress rupture, mechanical damping, impact; effects of chemical composition and structure on viscoelastic and strength properties; methods of mechanical property evaluation. Influences of plastics fabrication methods. Emphasis on recent research techniques and results. Individual laboratory projects investigating problems related to current research.
*F. J. McGarry, D. K. Roylance*

### 3.911 Professional Development for Technologists

Prereq.: —
G (Fall, Spring)
3-0-0 [P/D/F]
Can be repeated for credit

An overview of generally nontechnical topics useful to technical professionals in the industrial workplace, presented primarily by invited guests from industry. Topics include: personnel issues; presentation skills and report/proposal writing; career strategy; economics/finance; statistics in QC/QM, SPC; marketing/sales; legal/government issues; critical thinking; leadership; corporate strategy; project/engineering management.
*T. W. Eagar*

### 3.912 Polymer Processing

Prereq.: 3.064
G (Fall)
3-0-9 H-LEVEL Grad Credit

Survey of principal methods used in shaping of thermoplastic and thermosetting polymers and polymer-matrix composites. Phenomenological descriptions of hardware, and theoretical modeling of relevant chemical and transport phenomena. Role of processing in determining microstructure, properties, and performance of polymers.
*C. E. Scott*

### 3.92J Composite Materials

(Same subject as 1.594J)
Prereq.: 3.064
G (Fall)
3-2-4 H-LEVEL Grad Credit

Concepts underlying formation, characteristics, and behavior of plastics-based composites such as fiberglass laminates, structural sandwiches, plywood, and load-bearing adhesive joints. Typical components such as metals, glass, synthetic and natural adhesives, plastics, foams, wood, paper, fabrics, and rubber. Correlation between adhesion principles and physical behavior. Methods of design, analysis, fabrication, and testing. Discusses failure mechanisms of chemical and mechanical types. Individual laboratory projects investigating problems related to current research.
*F. J. McGarry*

### 3.930 Industrial Practice

Prereq.: —
U (Summer)
0-6-0 [P/D/F]

Enrollment restricted to students in Course III-B. Provides academic credit for first approved work assignment at a company. For reporting requirements consult faculty industrial practice coordinator.
*M. C. Flemings*

### 3.931 Industrial Practice

Prereq.: —
U (Summer)
0-6-0

Enrollment restricted to students in Course III-B. Provides academic credit for second approved work assignment at a company. For reporting requirements consult faculty industrial practice coordinator.
*M. C. Flemings*

### 3.932 Industrial Practice

Prereq.: —
G (Fall, Spring, Summer)
0-6-0 H-LEVEL Grad Credit
Can be repeated for credit

Provides academic credit for graduate students in Course III-B for approved work assignments at companies.
*M. C. Flemings*

### 3.94 Morphology of Polymers

Prereq.: 3.063
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-6

Examines polymer structure from the atomic to the micron scale. Structure of noncrystalline polymers, structure and classification of polymeric mesophases. Phase transformations, including classical nucleation theory and spinodal decomposition. Polymer blends, segmented and block copolymer morphology, structure of crystalline polymers, lamella and spherulites, deformation microstructures, fibers, microcomposites. Characterization methods such as wide- and small-angle x-ray scattering and transmission electron microscopy are also covered. Alternate years.
*E. L. Thomas*

### 3.941J Statistical Mechanics of Polymers

(Same subject as 10.668J)
Prereq.: 10.568 or permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 10.668J.
*A. Mayes, G. Rutledge*

### 3.951J Deformation and Fracture of Polymers

(Same subject as 2.921J)
Prereq.: 2.001 or 3.11
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 2.921J.
*I. V. Yannas*

### 3.96J Biomaterials — Tissue Interactions

(Same subject as 2.79J, 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

See description under subject 2.79J.
*I. V. Yannas, M. Spector*

### 3.97J Mechanical Forces in Organ Development and Remodeling

(Same subject as 2.785J, 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

See description under subject 2.785J.
*I. V. Yannas, M. Spector*

### 3.98 Polymer Synthetic Chemistry

Prereq.: 3.062 or equivalent
G (Spring)
3-0-6 H-LEVEL Grad Credit

An examination of the fundamental reaction mechanisms and chemistry of polymerization reactions with an emphasis on the synthesis of new advanced polymers.
*M. F. Rubner*

## Archaeology and Archaeological Science

### 3.980 Ancient Mexican Bells: Technology and Context

(3.171)
Prereq.: —
U (IAP)
1-1-1

Metalsmiths in ancient Mexico cast large numbers of bells from copper and bronze. Subject focuses on the technology of bell production and the meaning of bell sounds and their uses in ancient Mexican culture, through lectures and laboratory work. Replicas of ancient Mexican bells are made by copper smelting, alloying with tin, and lost-wax casting. Bell sound qualities are measured and related to materials properties and bell design characteristics. The ancient technology is compared to that of modern bellmaking.
*D. Hosler, S. M. Allen, L. W. Hobbs*

### 3.981 Materials in Human Experience

Prereq.: —
U (Spring)
3-3-3 HASS

Examines the ways in which people in ancient and preindustrial societies selected, evaluated, and used materials of nature, transforming them to objects of material culture. Some examples: concrete in Roman cities; cloth as power in the Inca state; the weaponry of the Crusades (Damascus steel). Explores ideological and aesthetic criteria often influential in materials development. Laboratory/workshop sessions provide hands-on experience with materials discussed in class. Enrollment may be limited. Alternate years.
*D. Hosler, L. W. Hobbs, S. Allen*

### 3.982 The Ancient Andean World

Prereq.: —
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: U (Fall)
3-0-6 HASS

Examines development of Andean civilization which culminated in the extraordinary empire established by the Inca. Archaeological, ethnographic, and ethnohistorical approaches. Particular attention to the unusual topography of the Andean area, its influence upon local ecology, and the characteristic social, political, and technological responses of Andean people to life in a topographically "vertical" world. Characteristic cultural styles of prehistoric Andean life.
*H. N. Lechtman*

### 3.983 The Aztec, the Maya, and Their Predecessors

Prereq.: —
U (Fall)
3-0-6 HASS

Examines origins and florescence of the impressive pre-Hispanic civilizations in area encompassed by contemporary Mexico and Guatemala using archaeological and ethnohistorical evidence. Considers factors such as distinct adaptive strategies demanded by the lowland rainforest and the highland environments, extensive interregional exchange, and sea trade with Central and South America in explaining the spectacular achievements of these indigenous American peoples.
*D. Hosler*

### 3.984 Materials in Ancient Societies: Metals
(Revised Units)

Prereq.: Permission of instructor
G (Fall)
3-6-3

The laboratory analysis of archaeological artifacts helps us understand the societies that produced them. This seminar-laboratory subject provides in-depth study of the technologies ancient societies used to produce metal objects from native and smelted metals. Seminars cover basic physical metallurgy and relate materials selection and processing to environment, exchange, aesthetics, political power, and cultural values. Senior undergraduates may register for subject under a Special Topics number; consult instructor.
*H. N. Lechtman*

### 3.985J Archaeological Science
(New)

(Same subject as 5.24J)
Prereq.: 3.091 or 5.11 or 8.01 or equivalent
U (Spring)
3-1-5 HASS

Pressing issues in archaeology as an anthropological science. Stresses the natural science and engineering methods archaeologists use to tackle them. Reconstructing time, space, and human ecologies provides one focus; materials technologies that transform natural materials to material culture provide another. Topics include 14C dating, ice core and palynological analysis, stable isotope chemistry of palaeodietary foodwebs, soil micromorphology and site formation, Pb isotope sourcing of metal artifacts, and microstructural and mechanical analyses of cementitious materials used in ancient monumental buildings.
*H. N. Lechtman, I. Oppenheim*

**3.986 Introduction to Archaeology**
(Revised Units)

(21A.103)
Prereq.: —
U (Fall)
3-2-4 HASS

Humans have modified their natural environment for over two million years. Archaeology reconstructs ancient human activity (subsistence, architecture, materials processing, and technology) and its environmental context from material remains using specialized techniques, many of which are laboratory-based. Drawing on case studies in contrasting environmental settings from the Americas and the Old World, subject considers these activities and the forces that shaped them. In laboratory sessions, students analyze various classes of archaeological materials, among them ceramics, stone, and metal.
*H. N. Lechtman, H. V. Merrick*

**3.987 Human Origins and Evolution**

(21A.105)
Prereq.: —
U (Spring)
3-0-6 HASS

Examines the dynamic interrelations among physical and behavioral traits of humans and environment and culture to provide an integrated framework for studying human biological evolution and modern diversity. Topics include issues in morphological evolution and adaptation; fossil and cultural evidence for human evolution from earliest times through the Pleistocene; evolution of tool use and social behavior; modern human variation and concepts of race. Includes study of stone artifacts and fossil specimens.
*H. V. Merrick*

**3.988 Africa — Past and Present: An Archaeological and Ethnographic Materials Perspective**

(21A.455)
Prereq.: —
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: U (Spring)
3-0-6 HASS

Examines prehistory and modern ethnographic diversity of technology on the African continent, with particular emphasis on the sub-Saharan region. Traces the course of human technological evolution from the earliest Plio-Pleistocene tool-making hominids to the modern ethnical diverse inhabitants of the continent, by way of topical case studies. These cases are centered on subsistence adaptations and technological responses. Includes lectures, experience handling prehistoric stone artifacts and modern ethnographic items, and ethnographic films.
*H. V. Merrick*

**3.989 Materials in Ancient Societies: Metals Laboratory**
(New)

Prereq.: 3.984
G (Spring)
0-6-3

The laboratory analysis of archaeological artifacts of metal. Follows on 3.984.
*H. N. Lechtman*

# Course 4

# Architecture

For degree requirements, see listing in Chapter VII under the School of Architecture and Planning.

**4.UR Undergraduate Research in Architecture**

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

**4.URG Undergraduate Research in Architecture**

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

Research and project activities, which cover the range represented by the various research interests and projects in the department. Students who wish a letter grade option for their work must register for 4 URG.
*Staff*

**4.101 Introduction to Architectural Design I**

Prereq.: —
U (Fall, Spring)
3-3-6

First introductory architectural design studio. Concerned with learning to read the built environment and understanding various ways of ordering architectural form. Intended to give students experience designing spaces through models. Lectures on architectural theory accompany individual design projects.
*E. Dunham-Jones*

**4.104 Introduction to Architectural Design II**

Prereq.: 4.101
U (Spring)
3-3-6

Second introductory architectural design studio concerned with a disciplined observation of the built environment. Intended to give students the experience of using drawings to record buildings. Emphasis on study of architectural places in their context by observing qualities of space, light, form and materials, and/or projects indicating various ways in which buildings, landscape, and urban form can be described and interpreted. Lectures, field studies, sketches, drawings.
*Architectural Design Staff*

**4.106 Design Skills Workshop**

Prereq.: Permission of instructor
G (Fall)
0-6-3

Supplements Level I Architectural Design Studio. Emphasizes acquisition of drawing and observational skills. Field trips, guest lectures, and presentations focus on issues specific to developing a design drawing repertoire. Individual tutorials in graphic skills. Intended for entering M.Arch. students.
*Architectural Design Staff*

**4.123, 4.124 Architectural Design: Level I[1]**

Prereq.: Permission of instructor
G (Fall, Spring)
0-12-6
Can be repeated for credit

**4.125, 4.126 Architectural Design: Level I[1]**

Prereq.: 4.104
U (Fall, Spring)
0-12-9
Can be repeated for credit

Establishes basic attitudes to architectural organization and its reflection in form. Includes projects where imposed conditions of site, program, and building system emphasize the interrelationship of fundamental elements in the pattern of decision making that constitutes architectural design. Develops presentations through drawings and models. 4.123, 4.124 intended for entering M.Arch. students; 4.125, 4.126 intended for juniors and seniors.
*Architectural Design Staff*

**4.131, 4.132 Architectural Design: Level II[1]**

Prereq.: 4.125, 4.126, 4.440
U (Fall, Spring)
0-12-9
Can be repeated for credit

**4.143, 4.144 Architectural Design: Level II[1]**

Prereq.: 4.123, 4.124 or 4.125, 4.126
G (Fall, Spring)
0-12-6 H-LEVEL Grad Credit
Can be repeated for credit

Projects develop awareness of the principal issues facing the contemporary architectural designer and the range of possibilities available for effective satisfaction of common environmental needs. Design for intensive, extensive, and multiple space uses. Buildings of multi-story construction. Considers natural and artificial environmental controls as they influence the design concepts and the installations associated with them.
*Architectural Design Staff*

**4.155, 4.156 Architectural Design: Level III[1]**

Prereq.: 4.144
G (Fall, Spring)
0-12-6 H-LEVEL Grad Credit
Can be repeated for credit

Emphasizes setting of architectural work as part of an organized community in projects having to do with built-up areas, as well as those on new sites. Studies plans for long-range development, giving students increasing experience in the analysis of real-life situations requiring program research.
*Architectural Design Staff*

[1]Note about the subjects in Architectural Design: The sequence in Architectural Design is a cumulative program. Its successful completion by the student is subject to evaluation by the staff independent of formal grades accumulated.

### 4.163J Urban Design

(Same subject as 11.332J)
Prereq.: Permission of instructor
G (Fall, Spring)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

The design of urban environments. Strategies for change in large areas of cities, to be developed over time, involving different actors. Fitting forms into natural, man-made, historical, and cultural outlooks; enabling desirable activity patterns; conceptualizing built form; providing infrastructure and service systems; guiding the sensory character of development. Involves architecture and planning students in joint work; requires individual designs or design and planning guidelines.
*J. P. de Monchaux, M. Dennis*

### 4.165 Architectural Design in Islamic Societies

Prereq.: 4.231
G (Spring)
0-12-9 H-LEVEL Grad Credit

Design studio exploring culture-specific themes related to architecture and the urban environment. Focuses on the design of a complex of buildings within a central urban area. Addresses the principal issues of form and cultural appropriateness faced by designers in Islamic and other nonwestern societies.
*A. Petruccioli*

### 4.171 The Space Between Workshop

Prereq.: 4.126
G (Fall)
3-2-7 H-LEVEL Grad Credit

Architectural design workshop focusing on understanding and designing the space between objects as well as the objects themselves.
*J. Wampler*

### 4.172 Form Language Workshop

Prereq.: 4.126
G (Spring)
3-2-7 H-LEVEL Grad Credit

Architectural design workshop: the investigation, retrieval, assemblage, production, and/or presentation of selected, salient, intrinsic organizational and/or associative "facts of form," attributes, principles, and/or behaviors.
*M. K. Smith*

### 4.173 Small Built-Collage

Prereq.: 4.143
G (Spring)
3-0-9 H-LEVEL Grad Credit

The intrinsic attributes/generative principles of built- and landscape-form/additive directional field organization. Progressions of intensification have included surfaced relief, "habitable" planar assemblages, territorial screens, and/or full-size furniture; tile, marble, granite surfaces and installations.
*M. K. Smith*

### 4.174 Design Workshop: School and Community

Prereq.: 4.126
G (Fall)
Units arranged H-LEVEL Grad Credit

Focus on the design and programming of K–12 schools in relation to community form, culture, and economy. Research into issues such as the "small school," the school as community center, and the impact of technology on school form; planning projects for school systems; investigation of alternatives to existing school models.
*R. Strickland*

### 4.181–4.185 Architectural Design Workshops

Prereq.: 4.131 or 4.143
G (Fall, Spring)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Form-making exercises that explore and/or inquire into a generic architectural design problem. The problem may be prototypical or a particular aspect of a whole project; it is often research-oriented and non-site specific.
*Architectural Design Staff*

### 4.188 Preparation for M.Arch. Thesis

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

Selection of thesis topic, definition of method of approach, and preparation of thesis proposal. Independent study supplemented by individual conference with faculty.
*Architectural Design Staff*

### 4.189 Preparation for M.Arch. Thesis

Prereq.: Permission of instructor
G (Fall, Spring)
Units arranged H-LEVEL Grad Credit

Selection of thesis topic, definition of method of approach, and preparation of thesis proposal. Independent study supplemented by individual conference with faculty.
*Architectural Design Staff*

### 4.ThG Graduate Thesis

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

Program of graduate research and writing of thesis; to be arranged by the student with supervising committee.

### 4.191, 4.192 Special Problems in Architectural Design

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

### 4.194 Special Problems in Architectural Design

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

### 4.195, 4.196 Special Problems in Architectural Design

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

### 4.199 Special Problems in Architectural Design

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*Architectural Design Staff*

### 4.203 Geometric Modeling

Prereq.: —
G (Fall)
Units arranged

Introduces the fundamentals of three-dimensional geometric modeling and associated computer-aided design and visualization applications in architecture, urban design, product design, and computer animation. Provides a theoretical foundation, an introduction to a selection of current hardware and software tools, and extensive opportunities to develop practical skills through hands-on lab sessions and regular practical exercises. A background of computational skills is an advantage, but not required. Successful completion enables students to acquire the skills necessary to undertake independent CAD and computer animation in design studios and professional settings, and to undertake more advanced subjects in this area.
*W. J. Mitchell, J. Dorsey, T. Nagakura*

### 4.204 Advanced Projects in Geometric Modeling

Prereq.: 4.203
G (Spring)
Units arranged H-LEVEL Grad Credit

Provides an opportunity to undertake advanced projects in geometric modeling and associated computer-aided design and visualization applications in architecture, urban design, product design, and computer animation.
*W. J. Mitchell, J. Dorsey, T. Nagakura*

**4.205 Foundations of Design and Computation**

Prereq.: Permission of instructor
G (Fall)
Units arranged H-LEVEL Grad Credit

An introduction to the computational treatment of design problems and processes. Presents basic theoretical ideas and provides an overview of the relevant literature. Gives particular attention to shape description, shape computation, shape grammars, and shape languages.
*W. J. Mitchell*

**4.206 Visualization**
(Revised Units)

Prereq.: —
U (Fall)
3-0-9

Explores the role of computer visualization as a representational medium. Emphasizes the visualization of light, color, surfaces, textures, volumes, scientific data, buildings, landscapes, and terrains, and introduces basic animation techniques. Real and imaginary environments are constructed, probed, and displayed. Also covers the relevant computer graphics methods.
*J. Dorsey*

**4.207 Advanced Topics in Design and Computation**

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

Provides an opportunity for detailed exploration of selected advanced topics in design and computation. Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*W. J. Mitchell*

**4.208, 4.209 Special Problems in Computation and Architecture**

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*Staff*

**4.210 Light, Color, and Computer Graphics**

Prereq.: 4.203 or 4.206
G (Spring)
3-0-6 H-LEVEL Grad Credit

Introduction to the effects of light and color in architecture. Applies computer graphics as the primary medium, along with direct observation, basic mathematical analysis, and other forms of representation, to help understand the complex and interconnected nature of these phenomena. Examines the distinction between natural and artificial light, the related topic of energy consumption, the color of light, and the role of all of these in the shaping of buildings. Also covers the relevant computer graphics techniques. Open to qualified undergraduates.
*J. Dorsey*

**4.214J Advanced Topics in Computer Graphics**
(New)

(Same subject as 6.838J)
Prereq.: 6.837 or 4.210
G (Spring)
3-0-9 H-LEVEL Grad Credit

In-depth study of an active research topic in computer graphics. Topics change each term. Readings from the literature, student presentations, short assignments, and a programming project.
*J. Dorsey*

**4.218, 4.219 Special Problems in Urban Housing**

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*M. Dennis, R. Goethert, R. Strickland*

**4.220 Urban Housing: Paris, London, New York**

Prereq.: Permission of instructor
G (Fall, Spring)
3-0-6 H-LEVEL Grad Credit
Can be repeated for credit

Analysis of the development of housing models and their urban implications in Paris, London, and New York City from the seventeenth century to the present. Focus on the French hotel, London row house, and New York City tenement and apartment building; twentieth-century housing reform movements and work by the London County Council, CIAM, and American public housing agencies.
*M. Dennis, R. Strickland*

**4.221 Architecture Studies Faculty Colloquium**

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

Required subject for all first-year S.M.Arch.S. students. Weekly presentations by faculty on a selected theme followed by discussion. Requirements include active student participation and a final paper reviewing the general theoretical issues raised by the theme and by each faculty presentation.
*Staff*

**4.222 Aspects of Office Practice**

Prereq.: Permission of instructor
G (Fall)
2-0-4 [P/D/F] H-LEVEL Grad Credit

An in-depth overview of the practice of architecture. Structured to convey the myriad of concerns and methodology associated with architectural project development. Introduces the student to the broad range of issues from office organization to steps and sequences required to facilitate, administer, and carry through an architectural project. Explores the architect's role as designer, project manager, contact with client from predesign through construction. Explores the expanding role of computers in architectural practice. Combines classroom discussions with site visits to several architectural offices.
*H. P. Portnoy*

**4.228, 4.229 Architectural Design Seminar**

Prereq.: 4.126
G (Fall, Spring)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Inquiries and/or explorations into a research topic related to architectural design taught in a seminar format. The work may supply the basis for an architectural design workshop and/or studio and/or lead a research proposal and/or publication.
*Architectural Design Staff*

**4.23J Special Interest Group in Urban Settlements: SIGUS Workshops**

(Same subject as 11.465J)
Prereq.: Permission of instructor
G (Fall, IAP, Spring)
Units arranged [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Interactive interdisciplinary workshops which focus on projects and practices on urban settlement issues in developing countries throughout the world. Participation by guest practitioners.
*R. Goethert, R. A. Gakenheimer, B. Sanyal*

**4.231 Architecture and Urban Contexts: Traditions, Conflicts, and Change**

Prereq.: Permission of instructor
G (Fall)
Units arranged H-LEVEL Grad Credit

Workshop concerned with understanding the built environment in Islamic and other non-western and Western societies and with developing appropriate strategies for change. Uses case studies on specific urban places that exhibit traditional, post-colonial, and modern characteristics of urban and architectural form, and that contain residences and established institutions reflecting traditional culture, as well as newer institutions reflecting international culture and organizations. Focus is on cultural and formal issues.
*A. Petruccioli*

**4.235 Urbanization and Design in Developing Countries**

Prereq.: Permission of instructor
G (IAP)
Units arranged H-LEVEL Grad Credit

Identifies and examines shifts in issues and approaches facing designers, from mass housing to core housing to site and services. Focus on housing design, land planning, and service provision. Extensive case studies from Africa, Latin America, and Asia.
*R. Goethert*

**4.236J Structuring Low-Income Housing Projects in Developing Countries**

(Same subject as 11.463J)
Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Examines relationship between housing needs and practice from the perspectives of government-sponsored projects. Emphasis on costs recovery, affordability, replicability, user selection, and project administration. Extensive case examples provide bases for comparisons.
*R. Goethert*

**4.237 The New Practitioner: Dialogue Tools and Techniques**
(Revised Units)

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

Explores a new paradigm of practice that considers dialogue essential for efficacious and creative design process. Focus on effective dialogue with non-traditional client groups: communities, the poor, and the generally excluded middle-income. Stress on hands-on experience with client groups. Supplemented with background readings and presentations by invited professionals.
*R. Goethert*

**4.238, 4.239 Special Problems in Non-Western Architecture**

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*A. Petruccioli*

**4.241J Theory of City Form**

(Same subject as 11.330J)
Prereq.: 11.001J or 4.252J or 11.301J
G (Spring)
Units arranged H-LEVEL Grad Credit

Theories about the form that settlements should take. Attempts a distinction between descriptive and normative theory by examining examples of various theories of city form over time. Concentrates on the origins of the modern city and theories about its emerging form, including the transformation of the nineteenth-century city and its organization. Analyzes current issues of city form in relation to citymaking, social structure, and physical design.
*J. Beinart*

**4.242J Advanced Seminar in City Form**

(Same subject as 11.331J)
Prereq.: 4.241J, 11.330J
G (Fall)
Units arranged H-LEVEL Grad Credit

Examines in greater depth themes from the basic subject in city form theory. Introduces new concepts from current research and practice for analysis by the seminar participants. Requirements include presentation to the seminar of a theoretical project undertaken by each student.
*J. Beinart*

**4.244J Urban Design Seminar**
(New)

(Same subject as 11.333J)
Prereq.: —
G (Spring)
2-0-7

Seminar on the basic theories of urban design. Includes morphological, structural, and procedural approaches. Case studies of important urban design efforts. Required for Urban Design certificate students.
*G. Hack*

**4.245J Cities of Tomorrow**

(Same subject as 11.335J)
Prereq.: Permission of instructor
G (Fall)
3-0-6 H-LEVEL Grad Credit

See description under subject 11.335J.
*D. Frenchman*

**4.247J Environmental Design Policy and Action**

(Same subject as 11.337J)
Prereq.: —
G (Spring)
3-0-6 H-LEVEL Grad Credit

See description under subject 11.337J.
*J. P. de Monchaux*

**4.248, 4.249 Special Problems in City Form**

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*J. Beinart, M. Dennis*

**4.250J Introduction to Urban Design and Development**

(Same subject as 11.001J)
Prereq.: —
U (Fall)
3-0-9 HASS

See description under subject 11.001J.
*L. Vale*

**4.252J Urban Design and Development**

(Same subject as 11.301J)
Prereq.: Permission of instructor
G (Fall)
3-0-9

See description under subject 11.301J.
*D. Frenchman*

**4.253J Urban Design Politics**

(Same subject as 11.302J)
Prereq.: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 11.302J.
*L. Vale*

**4.254J Design for Urban Development**

(Same subject as 11.303J)
Prereq.: 11.447
G (Spring)
2-4-6 H-LEVEL Grad Credit

See description under subject 11.303J.
*D. Frenchman, P. Roth*

**4.255J Site and Urban Systems Planning**
(Revised Units)

(Same subject as 11.304J)
Prereq.: Permission of instructor
G (Spring)
2-2-8

See description under subject 11.304J.
*G. Hack, K. Hill*

### 4.256J Housing and Urban Policy

(Same subject as 11.420J)
Prereq.: 11.200 or 4.144
G (Spring)
3-0-6 H-LEVEL Grad Credit

See description under subject 11.420J.
Consult Department Headquarters.

### 4.257J Property Rights Under Transition

(Same subject as 11.467J, 17.550J)
Prereq.: 11.210 or permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 11.467J.
*K. R. Polenske*

### 4.259 Special Problems in Environmental Design

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*J. Beinart, M. Dennis*

### 4.264 Environmental Psychology

Prereq.: —
U (Spring)
3-3-6 HASS

Presents social science theories and methods that apply to human transactions with a wide range of environments. Focuses on development of applied research skills relevant to successful designing for human use, from urban to machine interface. Readings reinforce lectures and fieldwork. Semester projects dovetail with student's field of interest.
*S. C. Howell*

### 4.265 Behavior in the Built Environment

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

Introduces behavioral science theories and methods as they relate to interactive affects of people in residential, working, and therapeutic settings. Readings supplement lectures and assigned fieldwork. Application of research methods such as behavior mapping, interviewing, and perceptual measures in systematic evaluations of environments in use and to design programming.
*S. C. Howell*

### 4.266J User Needs Programming

(Same subject as 11.329J)
Prereq.: Permission of instructor
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-6 H-LEVEL Grad Credit

A combination seminar and practicum in design programming. Combines readings and discussions on how to collect, select, and organize user information for use in the planning and design process. Students are placed with architecture firms, public or private community agencies that have active projects requiring assistance to inform their plans and designs.
*S. C. Howell*

### 4.269 Special Problems in Social Science and Architecture

Prereq.: Permission of instructor
Acad Year 1996-97: G (Fall, Spring)
Acad Year 1997-98: **Not offered**
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*S. C. Howell*

### 4.273 Introduction to Design Inquiry
(Revised Units)

Prereq.: —
G (Fall)
3-0-9

Explores, through exercises, lectures, and discussion, the nature and exercise of architectural intelligence; investigates design as processes located in individuals and in groups; seeks to understand design as argument, as claims for which reasons can be adduced, as logic in which there are explicit sets of elements and relations among them, and as experiment in which design and its results are themselves used to inform future designs or simply to inquire. Subject aims to open avenues for further research.
*W. L. Porter*

### 4.276 Design Research Seminar

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

What guarantees does the designer have that what is intended will be perceived? how can one come to make reliable judgments about the quality of designs? What constitutes good design? Considers design in several ways: as experience, as communication, as language, as problem framing and solving, as logic. Each of these has implications for how one thinks about and evaluates design quality and for how one designs an experiment to learn more about design and designing. Students' term project is to design such an experiment.
*W. L. Porter*

### 4.278, 4.279 Special Problems in Theory in Architecture

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*W. L. Porter*

### 4.280 Architecture Internship

Prereq.: 4.125 or 4.126
U (IAP)
Units arranged [P/D/F]
Can be repeated for credit

Work in an architect's office to gain experience, improve skills, and see the inner workings of an everyday architectural practice. Internships in all sizes of firms and in public and nonprofit agencies. Internships require full-time work for the entire IAP. Nonpaying.
*A. Pendleton-Jullian*

### 4.285, 4.286 Research Topics in Architecture Studies

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

Research work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*Staff*

### 4.288 Preparation for S.M.Arch.S. Thesis

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

### 4.289 Preparation for Architecture Studies — Ph.D. Thesis

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

Selection of thesis topic, definition of method of approach, and preparation of thesis proposal. Independent study supplemented by individual conference with faculty.
*Architecture Studies Staff*

**4.291 Special Problems in Architecture Studies**

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

**4.292, 4.293 Special Problems in Architecture Studies**

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

**4.294 Special Problems in Architecture Studies**

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

**4.295–4.298 Special Problems in Architecture Studies**

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

**4.299 Special Problems in Architecture Studies**

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*Staff*

**4.301 Foundations in the Visual Arts**

Prereq.: —
U (Fall, Spring)
2-4-6 HASS-D, Category 3

Introduces artistic thinking as a mode of discovery. Investigates art making as a means of thinking and how thinking and feeling are linked to making. Examines the ways artistic media (video, sculpture, computer imaging) as modes of thought inform our investigation and exploration of artistic vision. Lab fee.
*R. Taho*

**4.322 Introduction to Sculpture**

Prereq.: 4.301
U (Fall, Spring)
2-4-6 HASS

Examines fundamental issues in sculpture such as form in space, site, and context as well as issues of performance and the temporal dimensions in sculpture. Explores the relationships between concept, materials, and process. Lab fee.
*R. Taho*

**4.325 Advanced Sculpture**

Prereq.: 4.322
U (Fall, Spring)
2-4-6

Explores the conceptual and formal issues in sculpture, including site and environment, time, audience, the relation of material and object to context, and the relationship of sculpture to social and cultural issues.
*R. Taho*

**4.341 Introduction to Photography**

Prereq.: 4.301
U (Fall, Spring)
2-4-6 HASS

Investigates fundamental issues in photography and the nature of the photographic image as well as nontraditional ways of exploring the photographic vision. Explores relationship of image to language as well as the issues of meaning, interpretation, and their relationship to culture. Lab fee. Limited enrollment.
*E. Levine*

**4.351 Introduction to Video**

Prereq.: 4.301
U (Fall, Spring)
2-4-6 HASS

Explores fundamental issues in video such as the nature of the video image, narrative, and video time. Explores video as a sculptural, environmental, and narrative form. Looks at the issues of interpretation and meaning and how they relate to historical, social, and cultural issues. Limited enrollment.
*E. Levine*

**4.361 Dimensions of the Body**

Prereq.: 4.301, 4.322; 4.341 or 4.351
Acad Year 1996-97: U (Spring)
Acad Year 1997-98: **Not offered**
2-4-6 HASS

Explores how the body relates to thinking and making, how feelings and attitudes about the body affect the processes, judgments, and values involved in art and design. Looks at how issues of gender, culture, and history relate to issues of the body and art making.
*E. Levine*

**4.362 Dimensions of Time**

Prereq.: 4.301
Acad Year 1996-97: U (Spring)
Acad Year 1997-98: **Not offered**
2-4-6 HASS

Explores methods of conceiving and developing constructs about temporal experiences, investigating how we interact with various manifestations of time from mechanical clocks to biological time. Develops ideas about temporality and examines how time is embodied in history, memory, dreams, and everyday experiences as well as in other arts. Time and its manifestations are used as an inspiration for a series of studio-based projects. Lab fee.
*E. Levine*

**4.364 Dimensions in Space**

Prereq.: 4.301
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: U (Spring)
2-4-6 HASS

Examines the different spatial worlds we live in and construct. Explores the relationship between public and private spaces, sacred and profane, and the relationships of those experiences to the space of our bodies. Investigates how we move from one spatial construct to another and how these constructs are inseparable from the nature of our existence. Explores how our culture and society affect our conceptions and understanding of our spatial worlds.
*E. Levine*

**4.366 Advanced Projects in Visual Arts**

Prereq.: —
U (Fall, Spring)
2-4-6 HASS
Can be repeated for credit

Investigates conceptual and formal issues in different media or between media such as sculpture, photography, and video. Explores issues of representation, interpretation, and meaning, and how they relate to historical, social and cultural context.
*E. Levine*

**4.371 Art and the Environment**

Prereq.: —
U (Fall)
3-0-6 HASS

Reviews art, architecture, and celebrations and their positions in workday, religious, and political life. Reconsiders the present position of art and redefines the artist's options in the contemporary environment. Examines fact and changes effected by current science and technology vis-à-vis our place in nature and history.
*Staff*

**4.372 Environmental Art**

Prereq.: —
U (Spring)
0-4-8 HASS

Design and planning of environmental art installations in given and chosen existing settings. Emphasizes daring ideas in conjunction with realistic approach and possibility for execution. Artistic means ranging from large-scale painting and graphic design to kinetic architecture and natural elemental growth-and-change systems and to sound and video installations and performances.
*Staff*

**4.378 Special Problems in Environmental Art**

Prereq.: 4.372
U (Fall, Spring)
Units arranged
Can be repeated for credit

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*Staff*

### 4.381, 4.382 Advanced Visual Design

Prereq.: Permission of instructor
G (Fall, Spring)
0-9-12 H-LEVEL Grad Credit
Can be repeated for credit

Individual concepts, projects, design, and execution of installations, objects, and events in environmental art and performance involving elemental and science-technology means and media.
*Staff*

### 4.385–4.387 Special Problems in Environmental Art

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

Special work on an individual or group basis using specific means such as video, holography, and multimedia. Registration subject to prior arrangement of subject matter and supervision by staff.
*Staff*

### 4.388 Preparation for S.M.Vis.S. Thesis

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

Selection of thesis topic, definition of method of approach, and preparation of thesis proposal. Independent study supplemented by individual conference with faculty.
*E. Levine*

### 4.391–4.393 Special Problems in Visual Arts

Prereq.: 4.301
U (Fall, Spring)
Units arranged
Can be repeated for credit

### 4.394 Special Problems in Visual Arts

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

### 4.395–4.397 Special Problems in Visual Arts

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

### 4.398, 4.399 Special Problems in Visual Arts

Prereq.: 4.301, 4.322
G (Fall, IAP, Spring)
Units arranged [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*E. Levine*

### 4.401 Introduction to Building Technology

Prereq.: —
U (Spring)
3-3-6

Explores the application of building technology to architecture through considerations of building construction—materials and methods—and systems—structure, enclosure, climate and utility services, light, acoustics, fire safety, and accessibility. Includes lectures, laboratory exercises, site visits, and problem sets, but emphasizes a semester-long student investigation of a precedent building, culminating in a term paper.
*Building Technology Staff*

### 4.405 Materials and Construction

Prereq.: —
G (Fall)
3-1-5

Materials and methods of construction are essential elements for the built realization of design. Knowledge of the inherent as well as potential properties of building materials is applied to selected contemporary construction types and current processes of construction. Understanding of the integration of materials as functioning built form is fostered in lectures, case studies, and field trips. Attention is paid to the importance of working details as part of a technically coordinated whole. Several short exercises to test the student's skill in applying theory to practice.
*Building Technology Staff*

### 4.408, 4.409 Special Problems in Building Construction

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*Building Technology Staff*

### 4.411 Building Technology Laboratory

Prereq.: 8.02, 18.02
U (Fall)
2-4-6 Institute LAB

Concepts of building technology and experimental methods explored in a laboratory setting. Experimental projects include measurement of thermally driven airflows in model buildings, investigation of lighting intensity and glare, design and test of daylighting and passive solar strategies in model buildings, measurements of heat flow and thermal storage, and structural inquiry including load-deformation of materials, structural elements, and structural systems. Computers used for data acquisitions, analysis, and simulation.
*L. K. Norford*

### 4.42J Fundamentals of Energy in Buildings

(Same subject as 1.42J, 2.45J)
Prereq.: 8.02, 18.02
U (Fall)
3-0-9 REST

Introduction to energy fundamentals important to buildings. Conservation of energy. Properties of pure substances, gas mixtures, psychrometrics. Heat pumps and refrigeration cycles, limiting thermodynamic performance. Heat transfer within buildings and major components. Several creative design projects are assigned.
*L. R. Glicksman*

### 4.425 Energy in Building Design

Prereq.: Permission of instructor
G (Spring)
3-1-5

Explores aspects of thermal phenomena, thermal comfort, and climate relevant to building design, and applies concepts and methods to energy-efficient building design. Topics include thermodynamics, psychrometrics, comfort, indoor air quality and air distribution, solar radiation, climate, space heating and cooling loads, and lighting. Emphasizes a quantitative understanding of energy fundamentals; examples from practice, and design exercises.
*Q. Chen*

### 4.426 Energy, Environment, and Buildings Workshop

Prereq.: 4.425
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
4-2-6 H-LEVEL Grad Credit

Builds on an understanding of energy fundamentals by treating in depth one or more aspects of the influence of building design on energy use. Stresses life-cycle energy, including energy embodied in building materials, current information on material selection and its effect on indoor air quality, and the flow of energy and materials across the building envelope. Case studies and a significant design exercise.
*L. K. Norford*

### 4.427J Analysis and Design of Heating, Ventilating, and Air Conditioning Systems (New)

(Same subject as 2.46J)
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*

### 4.428, 4.429 Special Problems in Energy in Buildings

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*L. R. Glicksman, L. K. Norford*

### 4.43 Architectural Acoustics

Prereq.: 4.401
U (Fall)
3-0-6

Describes interactions between people and sound, indoors and outdoors, and uses this information to develop acoustical design criteria for architecture and planning. Physical principles of sound generation, propagation, and reception. Properties of materials for sound absorption, reflection, and transmission. Techniques and data used to provide good hearing conditions, and to control noise in rooms, buildings, and the environment. Practical examples and case-histories.
*C. J. Rosenberg*

### 4.440 Basic Structural Theory

Prereq.: 8.02, 18.02
U (Fall)
3-3-6 REST

Introduces the static behavior of structures and strength of materials. Reactions, truss analysis, stability of structures. Stress and strain at a point, shear and bending moment diagrams. Stresses in beams, Mohr's Circle, column buckling. Deflection of beams. Laboratory to solve structural problems by building simple models and testing them.
*Building Technology Staff*

### 4.441 Introduction to Building Structural Systems I

Prereq.: Permission of instructor
G (Spring)
3-0-6

Introduction to the principles of structural behavior, analysis, and design. Emphasis on individual structural elements and simple strategies for load carrying. Topics include estimating loads, introduction to statics, sectional attributes, and basic discussions of stress and strain; all set against background discussions of design and the overall issues affecting each structural element. Structural types examined include beams, trusses, simple frames, arches, and cables.
*Building Technology Staff*

### 4.442 Introduction to Building Structural Systems II

Prereq.: 4.441
G (Fall)
3-0-6

A continuation of 4.441, subject completes the exploration of structural elements: column buckling, frame analysis, and funicular structures: arches, cables. Discussion includes: bending as a form generator; review of overall strategies for load carrying, both vertically and laterally; how load-carrying strategies are implemented in systems; and how these systems are designed.
*Building Technology Staff*

### 4.446 Structures Design Workshop

Prereq.: 4.442
G (Spring)
2-4-6 H-LEVEL Grad Credit

Advanced methods of structural analysis in the development of structural form for architectural and urban design projects. Strategies of design for static and dynamic lateral loadings. Quantitative analysis, using computational methods, and qualitative analysis, reading critical literature, of innovative or trend-setting structures to better understand structural behavior, formal order, and tectonic character.
*Building Technology Staff*

### 4.448, 4.449 Special Problems in Structural Design

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

Supplementary structural design on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
*Building Technology Staff*

### 4.451 Building Systems

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

Exposes the student to the nature and variety of technological innovation in the building construction sector. Explores innovative approaches to rationalized methods of construction, as applied to generic building types. Views building systems as a total process, including the integration of project organization, production, and erection. Includes discussion of prefabrication and industrialization. Students are required to conduct individual research on related topics, including the presentation of relevant case studies.
*E. Dluhosch*

### 4.453 Building Technology in Real Estate Decision Making

Prereq.: —
G (Fall)
3-0-9

Reviews building systems and technologies with an emphasis on their impact on real estate decision making. Topics include building location, foundation and structural systems, enclosure, climate control, electrical and communications systems, plumbing, and fire and disaster safety. Assignments include weekly or bi-weekly analysis or case-study problems, as well as a semester-long analysis and proposal project focusing on an existing building asset. Grading is based upon all written work and the oral presentation of a final project.
*Building Technology Staff*

### 4.455 Integrated Building Systems

Prereq.: 4.405, 4.425, 4.441, 4.442
G (Fall)
3-2-7 H-LEVEL Grad Credit

Capstone of the technology sequence in the M.Arch. program. Emphasizes technologies related to structure, enclosure, climate, and light. Consideration of theory and issues related to manufacturing, construction and systems integration, and architectural design. Qualitative and quantitative analysis of precedents via computational tools, models, drawings, and written reports. Identification of appropriate technological systems for new designs on the basis of system integration and support of architectural objectives.
*P. J. Donnelly*

### 4.461 Building Simulation

Prereq.: Permission of instructor
G (Spring)
3-0-9

Mathematical modeling of air flow in building interior as well as whole-building systems for purposes of: building energy analysis, airflow analysis, and contaminant dispersal analysis; measurement of thermal and flow characteristics of buildings; and control of mechanical systems to affect thermal comfort, energy conservation, and indoor air quality. Uses computational fluid mechanics. Application to practical and current research problems.
*Building Technology Staff*

### 4.471 Control of Space Conditioning Systems

Prereq.: Permission of instructor
G (Fall, Spring)
3-0-9

Analysis of methods of conditioning buildings, their control and energy consumption. Topics include methods of heating, cooling, and ventilating buildings and associated control strategies. Control analysis and design based on root-locus plots, frequency response, and state-space methods. Energy management systems, including optimization and on-line analysis.
*L. K. Norford*

### 4.481 Building Technology Seminar

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

Introduction to ongoing research activities in building technology. Topics drawn from indoor air quality and thermal comfort, building systems analysis and control, building energy uses, and new building materials and construction techniques. Organized as a series of two- to three-week sessions that consider topics through readings, discussions, design and analysis projects, and student presentations.
*L. K. Norford, L. R. Glicksman*

### 4.488 Preparation for S.M.B.T. Thesis

### 4.489 Preparation for Building Technology Ph.D. Thesis

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

Selection of thesis topic, definition of method of approach, and preparation of thesis proposal. Independent study supplemented by individual conference with faculty.
*Building Technology Staff*

### 4.491–4.493 Special Problems in Building Technology

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

### 4.494 Special Problems in Building Technology

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

### 4.497, 4.498 Special Problems in Building Technology

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

### 4.499 Special Problems in Building Technology

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

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff. 4.491–4.493 are letter-graded.
*Building Technology Staff*

### 4.601 Introduction to Art History
(Revised Content)

Prereq.: —
U (Fall)
4-0-8 HASS-D, Category 3

Develops skills and knowledge essential to the description, analysis, and interpretation of visual artifacts through comparative analysis of works of art drawn from many cultures and time periods. Works in a wide range of media from the Americas, Europe, Africa, and Asia serve as case studies for investigation of the processes by which art objects acquire meanings and value for particular audiences. Also examines the questions art historians traditionally have asked about works of art and the means they have developed to answer them.
*M. Leja*

### 4.602 Modern Art and Mass Culture

Prereq.: —
U (Spring)
4-0-8 HASS-D, Category 3

Discusses the history of painting and design from the mid-nineteenth century through the 1980s in relation to emerging visual technologies (lithography, photography, the poster, photomontage), urban audiences, and consumer culture. Major artistic movements (Impressionism, Cubism, Russian Constructivism, Pop Art) are examined in relation to critical and theoretical writings about the relationship between the traditional arts and mass culture. No previous knowledge of art history is required.
*L. W. Kinney*

### 4.605 Introduction to the History and Theory of Architecture

Prereq.: —
U (Spring)
4-0-8 HASS-D, Category 3

Provides an outline of the history of architecture and urbanism from Ancient Egypt to the present. Analyzes buildings as the products of culture and in relation to the special problems of architectural design.
*D. H. Friedman*

### 4.607 Thinking About Architecture: In History and At Present

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

Subject on the problem of a history of architecture in terms not only of the formal end products, but also in relation to the structure of ideas and the cultures that have guided the formal productions. Addresses the present condition in architecture as much as the past and covers case studies from Vitruvius to the twentieth century.
*HTC Staff*

### 4.609 Seminar in the History of Art and Architecture

Prereq.: Four subjects in the 4.6xx series
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: U (Fall or Spring)
3-0-9

Examination of historical method in art and/or architecture focusing on periods and problems determined by the research interest of the faculty member leading the seminar. Emphasis on critical reading and viewing and direct tutorial guidance. Extensive discussion.
*D. H. Friedman, L. W. Kinney*

### 4.613 Civic and Residential Islamic Architecture

Prereq.: —
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: U (Spring)
3-0-6 HASS

Studies select examples of palatial, residential, commercial, and landscape architecture in the Islamic world in chronological order. Examines the formation and developments of architectural traditions, their possible models, their survival, their regional transformations, and the various influences at different historical junctions, all within the framework of the general Islamic culture.
*N. Rabbat*

### 4.614 Religious Architecture and Islamic Culture

Prereq.: —
U (Fall)
3-0-9 HASS-D, Category 3

Reviews the history of religious architecture in the Islamic World, and discusses its development in light of a changing Islam from a reform movement in seventh-century Arabia to a global power straddling three continents in the medieval period to the common religion of a number of competing empires in the premodern and smaller states in the modern periods. Presents Islamic architecture both as a full-fledged historical tradition and as a dynamic and interactive cultural catalyst that influenced and was influenced by the several civilizations with which it came into contact. This diversity of exchanges produced the various architectural manifestations that dot the historical and geographic map of the Islamic World.
*N. Rabbat*

### 4.615 The Architecture of Cairo

Prereq.: —
Acad Year 1996-97: U (Spring)
Acad Year 1997-98: **Not offered**
3-0-6 HASS

A thorough examination of the urban and architectural history of Cairo from the initial settlements on the site (640s) to the twentieth century. Investigates the development of Cairene architecture both in its Islamic and Mediterranean contexts and in light of the cultural, political, and social history of the city and the country. Focuses on the medieval period (eleventh to fifteenth century) when Cairo was the largest Mediterranean metropolis and a cultural and intellectual center of the Islamic world.
*N. Rabbat*

### 4.616 Cultural Signification in Architecture

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

Seminar on the issue of meaning in architecture. Establishes historical and theoretical frameworks for investigations. Analyzes traditions, transformations, and inventions in architecture as a conveyor of messages that transcend the stylistic, formal, and iconographic domains to include an assessment of some of the political, ideological, social, and cultural concerns of the builders and patrons both synchronically and diachronically. Critically reviews the methodologies and theoretical premises of studies on meaning and iconography in architecture.
*N. Rabbat*

### 4.617 Issues in Islamic Urbanism

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

Seminar on selected topics from Islamic urban history. Examines patterns of urbanization and architectural production in several cities. Discusses the leading factors in shaping civic forms and structures. Critically reviews the body of literature concerned with the Islamic City. Research paper required. Open to qualified undergraduates.
*N. Rabbat*

### 4.621 Orientalism and Representation

Prereq.: Permission of instructor
G (Fall)
Units arranged H-LEVEL Grad Credit

Seminar on the politics of knowledge, i.e., how political and ideological attitudes, concerns, and biases inform, and sometimes dictate, the representation, codification, and reproduction of knowledge. Critically reviews selected texts, illustrations, and institutional traditions which have been influential and/or paradigmatic in shaping the concepts and images of the Islamic Orient. Challenges the tacit assumptions and biases of the Orientalist conventions, and of the more recent essentialist trends in representing Islam. Research paper required.
*S. Bozdogan, N. Rabbat*

### 4.623 Technology and the Modern Project

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

Introduces technology as a historical, cultural, and philosophical problem integral to the project of modernity. Reviews aesthetic, ideological, and epistemological appropriations of technology in the architectural culture of the nineteenth and twentieth centuries, from "house-machines" to "virtual space." Focuses on the significance and status of technology in the critical debates concerning modernity — between dwelling and transience, between alienation and liberation, between critical programs of resistance to instrumental rationality and radical programs to extend the modern project further.
*S. Bozdogan*

### 4.624 Architecture and Modernization in the Middle East, 19th and 20th Centuries

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

A historical survey of important architectural and urban transformations in the Middle East from the nineteenth century modernizing reforms in the Ottoman Empire to the current crisis of secular nationalisms and the emergence of Islam as a contending project of civilization. Lectures cover such topics as the transformation of architectural education and practice, the introduction of modern architecture and planning, the work of western architects and firms, the emergence of nationalist, regionalist, and Islamicist discourses. Related readings for discussion.
*S. Bozdogan*

### 4.626 Architecture and Post-Colonial Identity

(Revised Content)

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

Addresses the role of architecture in the making of modern national identities in the late nineteenth and twentieth centuries. Focuses on construction and symbolism of national styles in architecture in Europe and in colonial/post-colonial contexts outside Europe. Investigates the complex interplay of the utopic and universalist visions of twentieth century modernism and the cultural and political expressions of nationhood through appropriation of history and/or vernacular traditions. Readings of key texts on nationalism, modernity, and identity.
*S. Bozdogan*

### 4.627 Special Problems in Islamic and Nonwestern Architecture

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

### 4.628, 4.629 Special Problems in Islamic and Nonwestern Architecture

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

Supplementary work on individual or group basis in the history, theory, and criticism of architecture and urban form in the Islamic World. Registration subject to prior arrangement for subject matter and supervision by staff.
*S. Bozdogan, N. Rabbat*

### 4.635 Renaissance Architecture

Prereq.: 4.605
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: U (Fall)
3-0-6 HASS

A history of the architecture of the fifteenth and sixteenth centuries in Italy. The formation and development of the classical style, drawing and model making, the relationship between architecture and the fine arts, buildings and their patrons, architectural theory, architecture and politics.
*D. H. Friedman*

### 4.638 Advanced Study in Renaissance Architecture

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

Seminar on a selected topic from Renaissance architecture. Requires original research and presentation of oral and written reports.
*D. H. Friedman*

### 4.639 Advanced Study in 16th-, 17th-, and 18th-Century Architecture

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

Seminar on a selected topic from architecture of the period. Requires original research and presentation of oral and written reports.
*H. A. Millon*

### 4.641 19th-Century Art

Prereq.: —
Acad Year 1996-97: U (Fall)
Acad Year 1997-98: **Not offered**
4-0-8 HASS

Survey of major artists and movements in nineteenth-century French painting, from Neo-Classicism to Post-Impressionism. Emphasis on emerging phenomena and concepts characteristic of the century, including: new visual technologies (lithography, photography, posters), the avant garde, the dealer/critic system, the museum and exhibition space, and the engagement of art with issues of class, gender, and politics.
*L. W. Kinney*

### 4.642 Advanced Study in Modern Art

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

Seminar on a selected topic from modern art, stressing theoretical or critical issues of contemporary concern. Requires original research and presentation of oral and written reports.
*L. W. Kinney*

### 4.643J Modern Art and Sexuality

(Subject meets with SP.476, SP.477J)
Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Explores the impact of recent critical thinking about representation, gender, and sexual difference on traditional understandings of modernism and methods of interpretation in the visual arts. Artists, issues, and types of imagery vary from year to year, but always include consideration of nineteenth-century painters of the nude (Courbet, Manet, Degas), theories of the construction of sexuality, and an introduction to feminist film theory. Open to qualified undergraduates.
*L. W. Kinney*

### 4.645 Selected Topics in Architecture — 1750 to the Present

Prereq.: 4.605
G (Spring)
3-0-6

General study of modern architecture in Europe and America in the context of architectural and social programs. Focuses on important problems and architectural proposals of a certain period to be analyzed using a variety of examples. Instead of supporting the idea of a linear development, it explores alternative "clusters" of architectural history. Required of all first-year M.Arch. Students. Midterm and final exams.
*HTC Staff*

### 4.647 Advanced Study in the Theory and History of Historic Preservation

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

Seminar on the development and critical issues of historic preservation. Analyzes the questions of monument and memory, historic preservation in the urban context, the polemics in modern preservation theory, and the design of new buildings in historic settings. Requires research, oral presentations, and written study.
*HTC Staff*

### 4.651 20th-Century Art

Prereq.: —
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: U (Fall)
4-0-5 HASS

The history of twentieth-century modernism and its internal contradictions, from Cubism and Futurism to the present. Considers especially the formation of anti-artistic attitudes in Dada and Surrealism, the constructivist and productivist project of integrating art and society and the contemporary post-modern critiques of the avant-garde.
*HTC Staff*

### 4.653 Advanced Study in 20th-Century Art

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

Seminar on a selected topic from twentieth-century art. Requires original research and presentation of oral and written reports.
*HTC Staff*

### 4.654–4.659 Advanced Study in Modern Architecture

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

Seminar or lecture on a selected topic in the architecture of the late eighteenth century to the present, in Europe and America. Requires original research and presentation of oral and written reports.
*S. Anderson, Staff*

### 4.660 The Architectural Agenda

Prereq.: Permission of instructor
G (Spring)
Units arranged H-LEVEL Grad Credit

Seminar on the history and the theory of architecture seen as an epistemological question within the wider context of knowledge. Discussion seminar that especially addresses problems in architectural research.
*HTC Staff*

### 4.661 Theory and Method in the Study of Architecture and Art

Prereq.: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Studies theoretical and historiographical works pertaining to the fields of architecture, art, and environmental studies. Members of seminar pursue work designed to examine their own presuppositions and methods. Open only to Ph.D. candidates and other advanced students.
*HTC Staff*

### 4.662 Advanced Study in the History of Urban Form

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

Seminar on a selected topic in the history of urban form. Requires original research and presentation of oral and written reports.
*D. H. Friedman*

### 4.663 History of Urban Form

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

Studies in the history of the physical city from Antiquity to the present, with points of special focus determined by the instructor. Analyzes the typologies of urban buildings, public places, and city plans in their relation to changing contexts of culture, politics, and the structure of public and private institutions.
*D. H. Friedman*

### 4.665 Contemporary Architecture and Critical Debate

Prereq.: 4.123 or 4.125
G (Fall)
3-0-6

Critical review of works, theories, and polemics of the last twenty-five years. Aim is a historical understanding of the period and the development of a meaningful framework to assess the present situation in architecture. Intended for M.Arch. students.
*E. Dunham-Jones*

### 4.666–4.669 Special Studies in the History, Theory, and Criticism of Architecture and Urban Form

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

Special topics in the history, theory, and criticism of architecture and urban form, varying at the discretion of the instructor.
*HTC Staff*

**4.680–4.682 Advanced Studies in the History, Theory, and Criticism of Art and Architecture**

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

Additional credit for extended project work in connection with a seminar with invariable units. Registration subject to prior arrangement for subject matter and supervision by staff.
*HTC Staff*

**4.689 Preparation for History, Theory, and Criticism — Ph.D. Thesis**

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

Selection of thesis topic, definition of method of approach, and preparation of thesis proposal. Independent study supplemented by individual conference with faculty.
*HTC Staff*

**4.691 Special Studies in the History, Theory, and Criticism of Art**

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

**4.692, 4.693 Special Studies in the History, Theory, and Criticism of Art**

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

Individual or group projects on topics in the history, theory, and criticism of art. Registration subject to prior arrangement for subject matter and supervision by staff.
*HTC Staff*

**4.694 Special Studies in the History, Theory, and Criticism of Art and Architecture**

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

**4.695 Special Studies in the History, Theory, and Criticism of Architecture and Urban Form**

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

**4.696–4.698 Special Studies in the History, Theory, and Criticism of Architecture and Urban Form**

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

**4.699 Special Studies in the History, Theory, and Criticism of Art and Architecture**

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

Individual and group projects in the history, theory, and criticism of art and/or architecture. Registration subject to prior arrangement for subject matter and supervision by staff.
*HTC Staff*

# Course 5

# Chemistry

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

### 5.UR Undergraduate Research

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

### 5.URG Undergraduate Research

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

Program of research to be arranged by the student and a departmental faculty member. Department Coordinator: K. A. Nelson.

### 5.03 Principles of Inorganic Chemistry I

Prereq.: 5.12
U (Spring)
4-0-8

Presents principles of chemical bonding and molecular structure, and their application to the chemistry of representative elements of the periodic system.
*A. Davison, R. R. Schrock*

### 5.04 Principles of Inorganic Chemistry II

Prereq.: 5.03
U (Fall)
4-0-8

Systematic presentation of the chemical applications of group theory. Emphasis is placed on the formal development of the subject and applications to determine the infrared and electronic spectra, magnetic properties, structure, and other features of transition metal complexes amenable to theoretical analysis. Elementary crystallography and space group theory. 5.61 background encouraged.
*C. C. Cummins*

### 5.05 Principles of Inorganic Chemistry III

Prereq.: 5.03, 5.04
G (Spring)
3-0-9 H-LEVEL Grad Credit

Extended treatment of some special topics of current interest in modern inorganic chemistry. The material is presented in two parts. The first part is a comprehensive overview of solid-state inorganic chemistry; the second part emphasizes main group chemistry.
*D. Seyferth, H. zur Loye*

### 5.061 Principles of Organometallic Chemistry
(New)

Prereq.: 5.03, 5.04
G (Fall)
2-0-4 H-LEVEL Grad Credit

A comprehensive treatment of organometallic chemistry of the transition metals with an emphasis on catalysis and mechanisms.
*R. R. Schrock*

### 5.062 Principles of Bioinorganic Chemistry
(New)

Prereq.: 5.03
G (Fall)
2-0-4 H-LEVEL Grad Credit

Choice, uptake, assembly of metal-containing units; control and use of metalions; metal folding and cross-linking of biomolecules; electron-transfer proteins; substrate bindings and activation; atom and group transfer chemistry; protein tuning of metal properties in biology; frontiers of bioinorganic chemistry.
*S. J. Lippard*

### 5.068 Physical Methods in Inorganic Chemistry

Prereq.: 5.03
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-6 H-LEVEL Grad Credit

Introduction to physical methods and their application to inorganic chemical compounds. Includes diffraction methods; electronic photoelectron spectroscopy; vibrational and rotational spectroscopy; magnetic measurements; including magnetic and electron spin resonance; Mössbauer spectroscopy; mass spectrometry; electrochemical measurements. Case histories, with the complementary use of selections of the various methods described.
*A. Davison*

### 5.07 Biological Chemistry

Prereq.: 5.12
U (Fall)
5-0-7 REST
Credit cannot also be received for 7.05

Description of the organization and functioning of living organisms in terms of molecular structures and processes. Chemical and physical properties of cell and tissue constituents, including carbohydrates, lipids, nucleic acids, and proteins. Origin of catalysis in biological systems. Metabolic synthesis and degradation of amino acids, carbohydrates, fats, and origins and fates of macromolecules as well as chemical bases of regulation and integration of metabolic phenomena.
*A. Klibanov, L. Stern*

### 5.071J Biochemistry Laboratory

(Subject meets with HST.410J, TOX.209)
Prereq.: 5.07, and 5.310 or 5.311
U (Spring)
2-8-2

Introduces experimental biochemistry techniques in four modules centered on the study of the enzyme β-galactosidase. Protein purification and enzyme kinetics are combined with basic molecular biology techniques that are essential for modern protein biochemistry. The four modules are 1) enzyme purification; 2) gene cloning; 3) site-directed mutagenesis; 4) enzyme kinetics. Kinetic analysis of wild type and mutant enzymes with substrates and inhibitors performed. Meets with graduate subject TOX 209, but assignments differ.
*J. Williamson, P. Dedon*

### 5.11 Principles of Chemical Science

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

Introduction to chemistry, with emphasis on basic principles and their applications. Includes atomic and molecular electronic structure, thermodynamics, acid-base and redox equilibria, chemical kinetics, reaction mechanisms, catalysis, and aspects of metal coordination chemistry and organic chemistry.
Fall Term: *R. W. Field, R. J. Silbey, Staff*
Spring Term: *A. M. Klibanov, W. H. Orme-Johnson*

### 5.12 Organic Chemistry I

Prereq.: 5.11
U (Fall, Spring)
5-0-7 REST

Introduction to organic chemistry. Development of basic principles to understand the structure and reactivity of organic molecules. Emphasis on substitution and elimination reactions and chemistry of the carbonyl group. Introduction to the chemistry of aromatic compounds.
Fall Term: *D. S. Kemp*
Spring Term: *S. L. Buchwald, G. C. Fu*

### 5.13 Organic Chemistry II

Prereq.: 5.11, 5.12
U (Spring)
5-0-7

Intermediate organic chemistry. Synthesis, structure determination, mechanism, and the relationships between structure and reactivity emphasized. Special topics in organic chemistry included to illustrate the role of organic chemistry in biological systems and in the chemical industry.
*R. L. Danheiser, Staff*

### 5.22J Biotechnology and Engineering

(Same subject as 10.02J, TOX.105J)
Prereq.: —
U (Spring)
4-0-5

Illustrates how the principles of chemistry, biology, and engineering are integrated to create new products for human health and consumption. Uses case-study format to examine recently developed products of pharmaceutical and biotechnology industries: how a product evolves from initial idea, through patents, testing, evaluation, production, and marketing. Emphasizes scientific and engineering principles, as well as the responsibility scientists, engineers, and business executives have for the consequences of their technology.
*J. M. Essigmann, R. S. Langer*

### 5.23J Atmospheric Chemistry

(Subject meets with 12.340J, 5.68)
Prereq.: 5.60
U (Spring)
3-0-9

See description under subject 12.340J.
*M. J. Molina, J. I. Steinfeld*

### 5.24J Archaeological Science
(New)

(Same subject as 3.985J)
Prereq.: 3.091 or 5.11 or 8.01 or equivalent
U (Spring)
3-1-5 HASS

Pressing issues in archaeology as an anthropological science. Stresses the natural science and engineering methods archaeologists use to tackle them. Reconstructing time, space, and human ecologies provides one focus; materials technologies that transform natural materials to material culture provide another. Topics include 14C dating, ice core and palynological analysis, stable isotope chemistry of palaeodietary foodwebs, soil micromorphology and site formation, Pb isotope sourcing of metal artifacts, and microstructural and mechanical analyses of cementitious materials used in ancient monumental buildings.
*H. N. Lechtman, I. Oppenheim*

### 5.310 Laboratory Chemistry

Prereq.: *5.12*
U (Fall, Spring)
2-8-2 Institute LAB

Introduces experimental chemistry for students who are not majoring in Course V. Principles and applications of chemical laboratory techniques, including preparation and analysis of chemical materials, measurement of pH, gas and liquid chromatography, visible-ultraviolet spectrophotometry, infrared spectroscopy, kinetics, data analysis, and elementary synthesis. Enrollment limited.
Fall Term: *W. H. Orme-Johnson, D. Seyferth*
Spring Term: *C. C. Cummins, Staff*

### 5.311 Introductory Chemical Experimentation

Prereq.: *5.12*
U (Fall)
2-8-2 Institute LAB

First term of a three-term laboratory subject sequence for Course V majors. Experimental work emphasizes development of fundamental laboratory skills and techniques: volumetric and colorimetric analysis; nuclear magnetic resonance; preparation, purification, and characterization of chemical substances; and data analysis. Enrollment limited to 50 students. Enrollment limited to Course V majors only.
*H. zur Loye, R. G. Griffin*

### 5.32 Intermediate Chemical Experimentation

Prereq.: 5.311 or 5.310, *5.13, 5.60*
U (Spring)
0-12-3

Experimental work more advanced than in 5.310 or 5.311, emphasizing thermodynamic and kinetic measurements of organic reactions; and synthesis, purification, and analysis of organic compounds employing IR, NMR, UV, mass spectroscopy, and thin layer and gas-liquid phase chromatography.
*S. C. Virgil, Staff*

### 5.33 Advanced Chemical Experimentation and Instrumentation

Prereq.: 5.32, *5.61*
U (Fall)
2-13-6

Advanced experimentation, with particular emphasis on chemical synthesis and the fundamentals of quantum chemistry illustrated through molecular spectroscopy. Projects include computer-interfaced IR, NMR, and picosecond laser spectroscopy; synthesis of organometallics under inert atmosphere; and polymer synthesis and characterization.
*K. A. Nelson*

### 5.43 Advanced Organic Chemistry

Prereq.: 5.13
U (Fall)
4-0-8

Application of structure and theory to the study of organic reaction mechanisms: stereochemical features including conformation and stereoelectronic effects; reaction dynamics, isotope effects and molecular orbital theory applied to pericyclic and photochemical reactions; special reactive intermediates including carbenes, carbanions and free radicals.
*G. C. Fu, S. C. Virgil*

### 5.44 Organometallic Chemistry

Prereq.: 5.43
G (Fall)
3-0-6 H-LEVEL Grad Credit

Examination of the most important transformations of organotransitionmetal species. Emphasizes basic mechanisms of their reactions, structure-reactivity relationships, and applications in synthesis.
*S. L. Buchwald*

### 5.45 Biorganic Chemistry

Prereq.: 5.43
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-6 H-LEVEL Grad Credit

Topics discussed in the context of protein and nucleic acid chemistry: binding forces, catalysis, enzyme models, allostery, complexation, cooperativity, transport, replication, recognition, and supramolecular assemblies.
*Staff*

### 5.46 NMR Spectroscopy and Organic Structure Determination

Prereq.: 5.43
G (Spring)
2-0-4 H-LEVEL Grad Credit

Applications of 1D and 2D $^{1}H$ and $^{13}C$ NMR spectroscopy to organic structure determination.
*S. Masamune, S. C. Virgil*

### 5.47 Tutorial in Organic Chemistry

Prereq.: 5.43, *5.511, 5.44 or 5.45*
G (Fall)
2-0-4 [P/D/F] H-LEVEL Grad Credit

Detailed discussions of the basic principles of importance to organic chemistry. The program is intended primarily for new graduate students in organic chemistry.
*S. L. Buchwald, R. L. Danheiser, G. C. Fu, S. Masamune, S. C. Virgil*

### 5.48J The Protein Folding Problem

(Same subject as 7.88J, 10.543)
Prereq.: 5.07 or 7.05 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 7.88J.
*J. A. King*

### 5.50 Enzymes: Structure and Function
(Revised Content)

Prereq.: 5.07, 5.12, 5.13
G (Spring)
4-0-8 H-LEVEL Grad Credit

Emphasis on methods available to elucidate the mechanisms of enzymes involved in peptide bond hydrolysis, phospho mono- and diester bond cleavage, oxidations and reductions (NADH, flavins, PQQ, pterin, and metal dependent), carbon-carbon bond forming and breaking reactions. Tools such as steady-state and presteady-state kinetics, isotope effect measurements, site-directed mutagenesis, mechanism base inhibitors applied to investigate mechanisms of enzymes that have been well-characterized structurally.
*J. Stubbe*

### 5.511 Synthetic Organic Chemistry I

Prereq.: 5.43
G (Fall)
3-0-6 H-LEVEL Grad Credit

Introduction to the design of syntheses of complex organic compounds.
*R. L. Danheiser, Staff*

### 5.512 Synthetic Organic Chemistry II

Prereq.: 5.511
G (Spring)
3-0-6 H-LEVEL Grad Credit

General methods and strategies for the synthesis of complex organic compounds.
*S. Masamune*

### 5.52 Advanced Biological Chemistry

Prereq.: Permission of instructor
G (Fall)
3-0-9 [P/D/F] H-LEVEL Grad Credit

Concepts and methods of biochemistry, with emphasis on quantitative aspects of problem analysis. Intended primarily for new graduate students in biological chemistry.
*L. Stern, J. Stubbe*

### 5.53 Molecular Structure and Reactivity

Prereq.: 5.13, 5.60
G (Fall)
3-0-6 H-LEVEL Grad Credit

Reaction mechanisms in organic chemistry: types of mechanisms, reactive intermediates, methods of investigation, relation of structure to reactivity.
*F. D. Greene*

### 5.56 Special Topics in Organic Chemistry

Prereq.: 5.511
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
2-0-4 H-LEVEL Grad Credit

Advanced topics of special current interest.
*Staff*

### 5.561 Chemistry in Industry

Prereq.: 5.13
G (Spring)
2-0-4 [P/D/F] H-LEVEL Grad Credit

Examination of recent advances in organic, biological, and inorganic chemical research in industry. Taught in seminar format with participation by scientists from industrial research laboratories.
*R. L. Danheiser, Staff*

### 5.60 Thermodynamics and Kinetics

Prereq.: 18.02, 5.11
U (Fall, Spring)
4-0-8 REST

Equilibrium properties of macroscopic systems. Basic thermodynamics: state of a system, state variables. Work, heat, first law of thermodynamics, thermochemistry. Second and third law of thermodynamics: entropy. Gibbs function, phase equilibrium properties of solutions. Chemical equilibrium of reactions in gas and solution phase. Rates of chemical reactions.
Fall Term: *C. W. Garland, B. Tidor*
Spring Term: *M. G. Bawendi, R. J. Silbey*

### 5.61 Physical Chemistry

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

Introductory quantum chemistry; particles and waves; wave mechanics; atomic structure and the Periodic Table; valence and molecular orbital theory; molecular structure; photochemistry.
*S. T. Ceyer*

### 5.62 Physical Chemistry

Prereq.: 5.60, 5.61
U (Spring)
4-0-8

Elementary statistical mechanics; transport properties; kinetic theory; solid state; reaction rate theory; chemical reaction dynamics.
*B. Tidor*

### 5.63 Molecular Spectroscopy: Laser and Magnetic Resonance Techniques

Prereq.: 5.61, *5.62*
Acad Year 1996-97: U (Spring)
Acad Year 1997-98: **Not offered**
3-0-9

Review of the interaction of radiation with quantum systems; introduction to the basic principles of modern optical and magnetic resonance spectroscopy. Topics in optical spectroscopy focus on an introduction to lasers and laser spectroscopic methods (laser-induced fluorescence, double resonance, resonance Raman, CARS, etc.). In magnetic resonance, topics include pulsed and Fourier-transform NMR and EPR, multiple dimensional techniques, magic-angle spinning, and quadrupole echoes. Applications of these methods to the studies of the structure and dynamics of liquids and solids.
*R. W. Field*

### 5.64 Biophysical Chemistry

(Subject meets with 7.71)
Prereq.: 5.60, 5.07 or 7.05
U (Fall)
3-0-9

Principles of biophysical chemistry introduced with discussion of the structure, folding, stability, and interactions of proteins and nucleic acids. Topics include: an overview of protein and nucleic acid structure; introductions to X-ray crystallography, spectroscopy, and 2D NMR; thermodynamic and kinetic aspects of protein folding; and principles of protein-nucleic acid interactions. Molecular mechanics introduced as a unifying tool that relates structure, molecular forces, and thermodynamic quantities. Meets with graduate subject 7.71. Students who take 7.71 cannot also receive credit for 5.64.
*J. R. Williamson, C. O. Pabo*

### 5.68 Kinetics of Chemical Reactions

(Subject meets with 12.340J, 5.23J)
Prereq.: 5.62
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-6 H-LEVEL Grad Credit

Experimental and theoretical aspects of reactive and inelastic molecular processes, including collision and transition — state theories, homogeneous reactions in gas and liquid phases, molecular beam scattering, information theory of kinetic processes. Case studies in chemical kinetics, including atmospheric chemistry and combustion dynamics. Advanced undergraduate students need permission of instructor.
*J. I. Steinfeld*

### 5.70 Introduction to Statistical Thermodynamics

Prereq.: 5.62
G (Fall)
3-0-6 H-LEVEL Grad Credit

Reviews classical thermodynamics and introduces elementary statistical mechanics, with applications to simple physical and chemical systems.
*I. Oppenheim*

### 5.72 Statistical Mechanics

Prereq.: 5.70, 5.73, 18.075
G (Spring)
3-0-6 H-LEVEL Grad Credit

Principles and methods of statistical mechanics. Classical and quantum statistics, grand ensembles, fluctuations, molecular distribution functions, and other topics in equilibrium statistical mechanics. Topics in thermodynamics and statistical mechanics of irreversible processes.
*C. Garland, I. Oppenheim*

### 5.73 Introductory Quantum Mechanics I

Prereq.: 5.61, 8.03, 18.03
G (Fall)
3-0-9 H-LEVEL Grad Credit

Fundamental concepts of quantum mechanics: wave properties, uncertainty principles, Schrodinger equation, operator and matrix methods. Basic applications to: one-dimensional potentials (harmonic oscillator), three-dimensional centrosymetric potentials (hydrogen atom), angular momentum and spin. Approximation methods: WKB method, variational principle, perturbation theory.
*M. G. Bawendi*

### 5.74 Introductory Quantum Mechanics II

Prereq.: 5.73, 18.075
G (Spring)
3-0-6 H-LEVEL Grad Credit

Time-dependent quantum mechanics, with emphasis on molecular spectroscopy. The traditional "eigenstate" picture of spectroscopy; the "wavepacket dynamics" pictures. Computer calculation of wavepacket dynamics and spectroscopic observables.
*K. A. Nelson*

### 5.76 Molecular Spectra and Molecular Structure

Prereq.: 5.61 or 5.73 or 8.05
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-6 H-LEVEL Grad Credit

Atomic spectra. Rotational, vibrational, and electronic spectra of diatomic and polyatomic molecules. Assignment of spectra. Structural parameters, molecular models, and effective Hamiltonian matrices. Breakdown of the Born-Oppenheimer approximation. Group theory, selection rules, normal coordinates. Laser spectroscopy.
*R. W. Field*

### 5.77J Topics in Metabolic Biochemistry

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

See description under subject 7.75J.
*G. M. Brown, J. Liu*

### 5.80 Special Topics in Chemical Physics

Prereq.: 5.73
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-6 H-LEVEL Grad Credit

Principles of Nuclear Magnetic Resonance, with emphasis on dynamics of spin systems.
*Staff*

### 5.89 Special Problems in Chemistry for Undergraduates

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

Program of study to be arranged by the student and a departmental faculty member. A letter grade is given in this activity.
*K. A. Nelson*

### 5.891 Special Topics in Chemistry for Undergraduates

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

Program of study to be arranged by the student and a departmental faculty member.
*Staff*

### 5.90 Special Problems in Chemistry

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

Directed research and study of special chemical problems. For graduate students only.
*D. Seyferth*

### 5.913 Seminar in Organic Chemistry

Prereq.: —
G (Fall)
1-0-2 [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

### 5.914 Seminar in Organic Chemistry

Prereq.: —
G (Spring)
1-0-2 [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Discusses current journal publications in organic chemistry by graduate students and staff members.
*R. L. Danheiser*

### 5.92 Seminar in Environmental Chemistry

Prereq.: —
G (Spring)
2-0-4 [P/D/F]
Can be repeated for credit

A seminar for graduate trainees in the "Chemistry of the Environment" program, and open to other interested graduate and advanced undergraduate students, which addresses technical, economic, political, and environmental issues of chemistry and society. Seminar is intended to give trainees participating in individual research groups that address widely different aspects of chemistry some common ground for thinking about environmental issues, and to develop a wide range of views about how society should deal with the interactions between chemical technology and the environment.
*J. I. Steinfeld*

### 5.931 Seminar in Physical Chemistry

Prereq.: —
G (Fall)
1-0-2 [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

### 5.932 Seminar in Physical Chemistry

Prereq.: —
G (Spring)
1-0-2 [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Discusses topics of current interest in physical chemistry by staff members and students.
*B. Tidor*

### 5.941 Seminar in Inorganic Chemistry

Prereq.: —
G (Fall)
1-0-2 [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

### 5.942 Seminar in Inorganic Chemistry

Prereq.: —
G (Spring)
1-0-2 [P/D/F] H-LEVEL Grad Credit
Can be repeated for credit

Discusses current research in inorganic chemistry by graduate students and staff.
*R. R. Schrock*

### 5.ThG Graduate Thesis

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

Program of graduate research, leading to the writing of a Ph.D. thesis; to be arranged by the student and an appropriate MIT faculty member.

# Course 6

# Electrical Engineering and Computer Science

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

## Basic Undergraduate Subjects

### 6.001 Structure and Interpretation of Computer Programs

Prereq.: —
U (Fall, Spring)
5-3-7 REST

Control of complexity in large programming systems. 1) Building abstractions: computational processes; higher-order procedures; compound data; data abstractions. 2) Controlling interactions: generic operations; self-describing data; message passing; streams and infinite data structures. 3) Meta-linguistic abstraction: interpretation of programming languages; machine model; compilation; embedded languages. Substantial weekly programming assignments are an integral part of the course. Enrollment may be limited. 4 Engineering Design Points.
*W. E. L. Grimson, R. A. Brooks*

### 6.002 Circuits and Electronics

Prereq.: 8.02 or 8.022; *18.03* or 18.06
U (Fall, Spring)
4-2-9 REST

Fundamentals of lumped networks, resistive elements and networks, energy storage elements, dynamics of first- and second-order networks, network equivalence theorems, electronic devices, circuits, and applications. Design exercises. Alternate week laboratory. Students with appropriate experience in electronic circuits may treat the 8.02 prerequisite as a corequisite. Enrollment may be limited. 4 Engineering Design Points.
*J. K. Roberge*

### 6.003 Signals and Systems

Prereq.: 6.001, 6.002
U (Fall, Spring)
4-2-9

Laplace transform and its applications to networks and electronic systems including feedback. Description of linear time-invariant systems in the time and frequency domains; convolution, Fourier series and integrals. Uncertainty relations and sampling theorems. Discrete-time systems and signals. Applications to analog and digital filtering systems and modulation systems. 4 Engineering Design Points.
*J. K. White*

### 6.004 Computation Structures

Prereq.: 6.001, 6.002
U (Fall, Spring)
4-3-8

Introduces architecture of digital systems, emphasizing structural principles common to a wide range of technologies. Multilevel implementation strategies; definition of new primitives (e.g., gates, instructions, procedures, processes) and their mechanization using lower-level elements. Analysis of potential concurrency; precedence constraints and performance measures; pipelined and multidimensional systems. Instruction set design issues; architectural support for contemporary software structures. 4 Engineering Design Points.
*S. A. Ward*

### 6.011 Introduction to Communication, Control, and Signal Processing

Prereq.: 6.003, 6.041
U (Fall, Spring)
4-0-8

Input-output and state-space models of linear systems driven by deterministic and random signals; time- and transform-domain representations. Sampling, discrete-time processing of continuous-time signals. State feedback, observers. Probabilistic models; stochastic processes, correlation functions, power spectra, whitening filters. Detection; matched filters. Least-mean square error estimation; Wiener filtering.
*A. V. Oppenheim, G. C. Verghese*

### 6.012 Electronic Devices and Circuits

Prereq.: *6.003,* 8.02
U (Fall, Spring)
4-0-8

Modeling of electronic devices and analysis of nonlinear circuits. Physical electronics of semiconductor junction and MOS devices. Relation of electrical behavior to internal physical processes; development of circuit models; understanding limitations of models. Application of incremental and large-signal techniques for analyzing circuits containing nonlinear devices. Analysis of bipolar and field effect transistor circuits, with examples chosen from single-ended and differential amplifiers, logic inverters, and other integrated circuits. Design project. 4 Engineering Design Points.
*C. G. Fonstad, Jr.*

### 6.013 Electromagnetic Fields and Energy

Prereq.: 6.002, 8.02
U (Fall)
4-0-8

Maxwell's equations and the Lorentz force law. Quasistatic forms of Maxwell's equations. Studies of electro-quasistatic fields and their sources through solutions of Poisson's and Laplace's equations. Steady conduction and polarization. Charge relaxation. Magneto-quasistatic approximation; magnetic boundary value problems, magnetization, induction, current induced in stationary and moving conductors. Electric and magnetic forces derived from energy. Electromagnetic waves. Extensive use of engineering examples.
*A. J. Grodzinsky*

### 6.014 Electrodynamics

Prereq.: 6.002; 8.02 or 8.022 or 8.02X
U (Spring)
4-0-8

Plane waves in three dimensions; radiation from elementary electric dipoles, current distributions, and arrays; diffraction and interference. Waves on continuous transmission lines, periodic structures, and dielectric and metallic waveguides; propagation and evanescence; energy flow and impedance matching. Phase and group velocity. Natural frequencies and modes of closed electromagnetic structures; coupling to resonant structures. Examples taken from the fields of quasistatics, acoustics, optics, and microwaves.
*J. A. Kong, D. H. Staelin*

### 6.021J Quantitative Physiology: Cells and Tissues

(Subject meets with 2.791J, 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

Principles of mass transport and electrical signal generation for biological membranes, cells, and tissues. Mass transport through membranes: diffusion, osmosis, chemically mediated, and active transport. Electric properties of cells: ion transport; equilibrium, resting, and action potentials. Kinetic and molecular properties of single voltage-gated ion channels. Laboratory and computer exercises illustrate the concepts. For juniors and seniors. Meets with graduate subject 6.521J, but assignments differ. Students interested in enhancing their written and oral presentation skills, see subject 6.080J. 4 Engineering Design Points.
*T. F. Weiss, D. M. Freeman*

### 6.022J Quantitative Physiology: Organ Transport Systems

(Subject meets with 2.792J, 2.796J, 6.522J, HST.542J)
Prereq.: 2.006 or 6.013; *6.021J*
U (Spring)
4-2-6

Application of the principles of energy and mass flow to major organ systems of humans and other mammals. Mechanisms of regulation and homeostasis. Anatomical, physiological, and pathophysiological features of the cardiovascular, respiratory, and renal systems. Emphasis on those systems, features, and devices that are most illuminated by the methods of physical sciences. Laboratory work includes some animal studies. Waiver of 6.021J by permission of instructor. 2 Engineering Design Points.
*R. G. Mark, R. Kamm*

### 6.023J Quantitative Physiology: Sensory and Motor Systems

(Same subject as 2.793J, 16.401J, HST.543J)
Prereq.: 2.003 or 6.003 or 16.060
U (Spring)
3-2-7

Studies of sensory and motor physiology, with objectives of establishing quantitative models. Peripheral signal processing in eye, ear, and vestibular systems. Physiology and psychophysics of audition, vision, orientation, and body stabilization. Organization of neuromuscular and proprioceptive systems at level of spinal cord reflex. Postural control and kinetics of movement. Supplemented by laboratory exercises. 6.021J recommended background. 3 Engineering Design Points.
*L. S. Frishkopf, C. Wall III, N. Hogan, L. Young*

### 6.033 Computer System Engineering

Prereq.: 6.004
U (Spring)
4-0-8

Topics on the engineering of computer software and hardware systems: techniques for controlling complexity; networks and distributed systems; atomicity and coordination of parallel activities; recovery and reliability; privacy of information; impact of computer systems on society. Case studies of working systems and outside reading in the current literature provide comparisons and contrasts. 4 Engineering Design Points.
*M. F. Kaashoek*

### 6.034 Artificial Intelligence

Prereq.: 6.001
U (Fall)
4-4-4

Studies the ideas and techniques that enable computers to behave intelligently. Applications of search, constraint propagation, rule chaining, frame inheritance, and other problem-solving techniques in expert systems, robotics, and natural-language understanding. Regularity-based, explanation-based, and neural net learning. Symbolic and nonsymbolic approaches to sensing, locomotion, and manipulation in complicated environments.
*P. H. Winston, T. Lozano-Pérez*

### 6.035 Computer Language Engineering

Prereq.: 6.170
U (Fall)
4-4-4

Analyzes issues associated with the implementation of higher-level programming languages. Fundamental concepts, functions, and structures of compilers. The interaction of theory and practice. Using tools in building software. Includes a multi-person project on compiler design and implementation. 8 Engineering Design Points.
*J. V. Guttag*

### 6.036 Problem-Solving Paradigms

Prereq.: 6.034
U (Spring)
4-0-8

Investigates the basic paradigms for problem solving including the use (and misuse) of logic, procedural knowledge, debugging skills, and the reformulation of problems. Detailed study of natural deduction, pattern-directed procedures, and systems for reasoning effectively and efficiently within stereotypical situations. Examples drawn from mathematics, natural language comprehension, and programming. Applications of theoretical results to human problem solving and education.
*C. E. Hewitt*

### 6.038 Artificial Intelligence in Practice

(New)

Prereq.: 6.034
U (Spring)
3-4-5

Investigates the application of the methods and tools of artificial intelligence to problems in science, engineering, business, and entertainment. Emphasis on mastery and application of programs embodying many basic representations and problem-solving methods in artificial intelligence, including search, constraint propagation, rule-chaining, planning, deduction, and machine learning. Includes an individual and a multi-person project on real problems drawn from a variety of disciplines. Substantial programming experience required. 8 Engineering Design Points.
*T. Lozano-Pérez*

### 6.041 Probabilistic Systems Analysis

(Subject meets with 6.431)
Prereq.: 18.02
U (Fall, Spring)
4-0-8 REST

Modeling, quantification, and analysis of uncertainty. Formulation and solution in sample space. Random variables, transform techniques, simple random processes and their probability distributions, Markov processes, limit theorems, elements of statistical inference, and decision making under uncertainty. Interpretations, applications, and lecture demonstrations. Meets with graduate subject 6.431, but assignments differ.
*A. W. Drake*

### 6.042J Mathematics for Computer Science

(Same subject as 18.062J)
Prereq.: 18.02 or 18.023 or 18.024
U (Fall, Spring)
5-0-7

Mathematical tools and methods for computer science and engineering. Emphasis on development of rigorous thinking, analytical skills, and mathematical sophistication while learning elementary discrete mathematics. Topics: mathematical proofs; induction and well-ordering; divisibility and congruences; asymptotic notation and growth of functions; sets, relations, functions, and graphs; counting theory; recurrences and generating functions; discrete probability.
*C. E. Leiserson, F. T. Leighton, R. L. Rivest*

### 6.044J Computability, Logic, and Programming

(Same subject as 18.423J)
Prereq.: 6.042J or 18.310
U (Spring)
3-0-9

Introduction to theory of programming languages, logic, and computability. Operational behavior and mathematical meaning of imperative and functional programs. A fully developed and implemented "substitution model" for the Scheme language. Logical assertions and program specification. Validity, truth, and provability. Undecidable problems in logic and programming. Incompleteness theorem for first-order arithmetic. Introduction to denotational semantics of programs.
*A. R. Meyer*

### 6.045J Automata, Computability, and Complexity

(Same subject as 18.400J)
Prereq.: 6.046J
U (Spring)
4-0-8

Slower paced than 6.840J/18.404J. Introduces basic mathematical models of computation and the finite representation of infinite objects. Finite automata and regular languages. Context-free languages. Turing machines. Partial recursive functions. Church's Thesis. Undecidability. Reducibility and completeness. Time complexity and NP-completeness. Probabilistic computation. Interactive proof systems.
*N. A. Lynch*

### 6.046J Introduction to Algorithms

(Same subject as 18.410J)
Prereq.: 6.001; 6.042J
U (Fall, Spring)
4-0-8

Techniques for the design and analysis of efficient algorithms, emphasizing methods useful in practice. Topics: sorting; data structures for sets: search trees, heaps, hashing; graph algorithms: shortest paths, depth-first search, network flow; computational geometry; integer arithmetic: gcd, primality; polynomial and matrix calculations; dynamic programming; amortized analysis; NP-completeness and approximation algorithms.
*C. E. Leiserson, M. Goemans*

**6.061 Introduction to Electric Power Systems**

Prereq.: 6.002, 6.013
U (Spring)
3-0-9

Fundamentals of energy-handling electric circuits and electromechanical apparatus. Modeling of magnetic field devices and description of their behavior using appropriate models. Simplification of problems using transformation techniques. Power electric circuits, magnetic circuits, lumped parameter electromechanics, elements of linear and rotating electric machinery. Modeling of synchronous, induction, and dc machinery.
*J. L. Kirtley, Jr.*

**6.070J Electronics Project Laboratory**

(Same subject as SP.705J)
Prereq.: —
U (IAP, Spring)
2-2-2

Introduction to electronics test equipment such as oscilloscopes, meters (voltage, resistance inductance, capacitance, etc.), and signal generators. Hands-on format emphasizes individual instruction and development of skills, such as soldering, assembly, and troubleshooting. Students build and keep an electronics kit, such as AM-FM superhetrodyne radio, to serve as the vehicle for learning about electronics test and measurement equipment. No previous background in electronics required.
*J. K. Vandiver, B. D. Wedlock*

**6.071 Introduction to Electronics**

Prereq.: 18.01, *8.02*
U (Fall)
4-2-6 REST

Introductory subject suitable for students with little or no previous background in electronics. Elementary network theory, diode and transistor circuits, analysis and design of analog and digital circuits. Examples emphasize uses of electronics in experimental science. Alternate week laboratory. 4 Engineering Design Points.
*L. D. Braida, B. D. Wedlock*

**6.080J Practicum in Engineering Writing and Oral Presentation—Quantitative Physiology: Cells and Tissues**

(Same subject as 21W.802J)
Prereq.: —
U (Fall)
2-0-4

See description under subject 21W.802J.
*T. F. Weiss, E. Barrett, D. M. Freeman*

**6.090–6.094 Special Subjects in Electrical Engineering and Computer Science**

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

**6.095–6.099 Special Subjects in Electrical Engineering and Computer Science**

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

Basic undergraduate subjects not offered in the regular curriculum. Consult Department to learn of offerings for a particular term. Registration by permission of instructor.
*A. C. Smith*

## Undergraduate Laboratory Subjects

**6.100 Electrical Engineering and Computer Science Laboratory**

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

Individual experimental work related to electrical engineering and computer science not covered by other subjects. Student must make arrangements with a project supervisor and file a proposal endorsed by the supervisor. Departmental approval required. Written report to be submitted upon completion of work. If 6.100 is used to satisfy Departmental Laboratory Requirement, student must register for 12 units of laboratory credit in the term the work is done. Consult Department Undergraduate Office early in the term.
*A. C. Smith*

**6.101 Introductory Analog Electronics Laboratory**

Prereq.: 6.002 or 6.071
U (Fall, Spring)
2-9-1 Institute LAB

Introductory experimental laboratory focusing on the design and construction of analog electronic circuits. Initial lectures and laboratory projects investigate the performance and characteristics of discrete and integrated-circuit components. Design and implementation of independent project. Provides opportunity to focus on real-world problems with complex objectives and solutions that involve tradeoffs and the use of engineering judgement. 12 Engineering Design Points.
*B. M. Roscoe*

**6.111 Introductory Digital Systems Laboratory**

Prereq.: 6.002 or 6.071 or 16.040
U (Fall, Spring)
3-7-2 Institute LAB

Lectures and labs on digital logic, flipflops, PALs, counters, timing, synchronization, finite-state machines and microprogrammed systems prepare students for the design and implementation of a final project of their choice, e.g., games, music, digital filters, graphics, etc. Possible use of lab report for Phase II of the Writing Requirement. Six extra units possible via adding 6.919 after project proposal. 12 Engineering Design Points.
*J. L. Kirtley, Jr., D. E. Troxel*

**6.115 Microcomputer Project Laboratory**

Prereq.: 6.111 or 6.004
U (Fall)
3-6-3

Students complete three projects involving microprocessors. The first introduces basic hardware, software, and development tools and provides experience with interrupts, A/D converters, communication, digital signal processing and control. The second emphasizes planning, testing, and achieving specific goals and involves a team effort to build a microprocessor system. The third, of the student's choice, emphasizes creativity and uniqueness. Lectures accompany the first two projects and cover related material. 12 Engineering Design Points.
*R. D. Thornton*

**6.121J Bioelectronics Project Laboratory**

(Same subject as HST.575J)
Prereq.: 6.002 or 6.071
U (Spring)
2-8-2 Institute LAB

Project Laboratory in electronic instrumentation, interfacing the analog and digital world. Students specify design, implement, and evaluate biomedical instruments, including several interrelated analog and digital subsystems. Extensive use of integrated analog circuits and a microprocessor. Classroom development of analytic models for complex functional components and the measurement process in the context of a longitudinal laboratory project. Written report will meet the requirements of Phase II writing. 12 Engineering Design Points.
*S. K. Burns, R. G. Mark*

**6.151 Semiconductor Devices Project Laboratory**

Prereq.: 6.152J
U (Spring)
0-12-0 Institute LAB

Student use of the Microelectronics Laboratory facilities for individual or team projects in the area of design, fabrication, modeling, and characterization of individual MOS or bipolar devices, microsensors or microactuators, and integrated circuits using these devices. Each term, the project topics are selected to fit the general areas of development in the Laboratory. Enrollment limited. 12 Engineering Design Points.
*M. A. Schmidt, C. G. Sodini*

### 6.152J Microelectronics Processing Technology

(Same subject as 3.155J, 10.480J)
Prereq.: Permission of instructor
U (Fall, Spring)
3-4-5

Introduces the theory and technology of integrated-circuit fabrication. Lectures and laboratory sessions on basic processing techniques such as diffusion, oxidation, epitaxy, photolithography, chemical vapor deposition, and plasma etching. Emphasis on the interrelationships between material properties, device structure, and the electrical behavior of devices. Provides background for thesis work in microelectronics or for 6.151. 6 Engineering Design Points.
*M. A. Schmidt, C. G. Sodini, H. H. Sawin, C. V. Thompson, K. K. Gleason, L. C. Kimerling*

### 6.161 Modern Optics Project Laboratory

Prereq.: 6.003, 6.013
U (Fall)
2-8-2 Institute LAB

Lectures, laboratory exercises, and projects in modern optics. Topics: polarization properties of light, reflection and refraction, coherence and interference, Fraunhofer and Fresnel diffraction, imaging and transforming properties of lenses, spatial filtering, coherent optical processors, holography, optical properties of materials, lasers, nonlinear optics, electro-optic and acousto-optic materials and devices, optical detectors, fiber optics, and optical communication. Seniors may use this laboratory to find an advanced undergraduate project. 12 Engineering Design Points.
*C. Warde*

### 6.163 Strobe Project Laboratory

Prereq.: —
U (Fall, Spring)
2-8-2 Institute LAB

A project laboratory for experiments, dealing mainly with the characteristics of electronic flash sources of light and their applications to photography and measurement problems. A program of experimentation concerned with electronic flash, organized with each group of students at the start of the term. 12 Engineering Design Points.
*C. H. Mazel*

### 6.170 Laboratory in Software Engineering

Prereq.: 6.001
U (Spring)
3-9-3

Introduces concepts and techniques relevant to the production of large software systems. Students taught a programming method based on the recognition and description of useful abstractions. Topics: programming methodology; procedural, data, and control abstractions; specifications; design methods, and testing. Several programming projects of varying size undertaken by students working singly and in groups. 12 Engineering Design Points.
*B. H. Liskov*

### 6.182 Psychoacoustics Project Laboratory

Prereq.: —
Acad Year 1996-97: U (Spring)
Acad Year 1997-98: **Not offered**
3-4-5 Institute LAB

Introduces the methods used to measure human auditory abilities. Discusses auditory function, principles of psychoacoustic measurement, models for psychoacoustic performance, and experimental techniques. Project topics: absolute and differential auditory sensitivity, operating characteristics of human observers, span of absolute judgment, adaptive measurement procedures, scaling sensory magnitudes. Oral presentation and written report. Knowledge of probability helpful. Alternate years. 12 Engineering Design Points.
*L. D. Braida*

### 6.190–6.194 Special Laboratory Subjects in Electrical Engineering and Computer Science

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

### 6.195–6.198 Special Laboratory Subjects in Electrical Engineering and Computer Science

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

Laboratory subjects not offered in the regular curriculum. Consult Department to learn of offerings for a particular term. Registration by permission of instructor.
*A. C. Smith*

### 6.199 Advanced Undergraduate Project

Prereq.: —
U (Fall, IAP, Spring)
0-12-0

Research project for those students completing the S.B. degree; to be arranged by the student and an appropriate MIT faculty member. Students who register for this subject must consult Department Undergraduate Office. Students who are completing a project that was originally started as 6.ThU must register under that subject number.
*A. C. Smith*

# Advanced Undergraduate Subjects and Graduate Subjects by Area

## Systems Science and Control Engineering

### 6.231 Dynamic Programming and Stochastic Control

Prereq.: 6.041 or 18.313 or 18.440 or 18.100
G (Fall)
3-0-9 H-LEVEL Grad Credit

Sequential decision making via dynamic programming. Unified approach to optimal control of stochastic dynamic systems and Markovian decision problems. Applications in linear-quadratic control, inventory control, resource allocation models. Optimal decision making under perfect and imperfect state information. Certainty equivalent and open loop-feedback control, self-tuning controllers. Infinite horizon problems, successive approximation, policy iteration. Discounted problems, stochastic shortest path problems, average cost problems. Optimal stopping, scheduling, and control of queues. Approximations and neurodynamic programming.
*D. P. Bertsekas*

### 6.241 Dynamic Systems and Control

Prereq.: 6.003, 18.06
G (Fall)
4-0-8 H-LEVEL Grad Credit

Linear, discrete- and continuous-time, multi-input-output systems in control, related areas. Least squares and matrix perturbation problems. State-space models, modes, stability, controllability, observability, transfer function matrices, poles and zeros, minimality. Internal stability of interconnected systems, feedback compensators, state feedback, optimal regulation, observers, observer-based compensators. Measures of control performance, robustness issues using singular values of transfer functions. Introductory ideas on nonlinear systems. Recommended prerequisite: 6.302.
*M. A. Dahleh, G. C. Verghese*

### 6.242 Advanced Linear Control Systems

Prereq.: 18.06, 6.241
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Introduction to uncertain multivariable control systems, modeling assumptions and objectives. Stability of linear time invariant systems, coprime factorization, parametrization of all stabilizing compensators. Design using $H_2$, $H\infty$ $L^1$-optimization. Stability and performance robustness in the presence of structured uncertainty. Special topics. Alternate years.
*M. A. Dahleh*

### 6.243J Dynamics of Nonlinear Systems

(Same subject as 2.156J, 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

Introduction to nonlinear deterministic dynamical systems. Nonlinear ordinary differential equations. Planar autonomous systems. Fundamental theory: Picard iteration, contraction mapping theorem, Bellman-Gronwall lemma. Stability of equilibria by Lyapunov's first and second methods. Feedback linearization. Application to nonlinear circuits and control systems. Alternate years.
*J. L. Wyatt, Jr., M. Dahleh, R. Ramnath, N. Hogan*

### 6.245 Multivariable Control Systems
(Revised Units)

Prereq.: 6.241 or 16.31
G (Spring)
3-0-9 H-LEVEL Grad Credit

Computer-aided design methodologies for synthesis of multivariable feedback control systems. Performance and robustness trade-offs. Model-based compensators; separation properties. Linear-quadratic and Kalman filter designs. Integral control and other dynamic augmentation. Linear-quadratic-gaussian compensators; loop transfer recovery. Introduction to H-∞ design and mu-synthesis. Model and compensator simplification. Nonlinear effects. Computer-aided design homework using models of physical processes.
*M. Athans*

### 6.251J Introduction to Mathematical Programming

(Same subject as 15.081J)
Prereq.: 18.06
G (Fall)
4-0-8 H-LEVEL Grad Credit

Introduction to linear optimization and its extensions emphasizing both methodology and the underlying mathematical structures and geometrical ideas. Covers classical theory of linear programming as well as some recent advances in the field. Topics: simplex method; duality theory; sensitivity analysis; network flow problems; decomposition; integer programming; interior point algorithms for linear programming; introduction to combinatorical optimization and NP-completeness.
*J. N. Tsitsiklis, D. Bertsimas*

### 6.252J Nonlinear Programming

(Same subject as 15.084J)
Prereq.: 18.06, 18.100
G (Spring)
3-0-9 H-LEVEL Grad Credit

A unified analytical and computational approach to nonlinear optimization problems. Unconstrained optimization methods include gradient, conjugate direction, Newton, and quasi-Newton methods. Constrained optimization methods include feasible directions, projection, interior point, and Lagrange multiplier methods. Convex analysis, Lagrangian relaxation, nondifferentiable optimization, and applications in integer programming. Comprehensive treatment of duality theory. Applications drawn from control, communications, power systems, and resource allocation problems.
*D. P. Bertsekas, J. F. Shapiro*

### 6.262 Discrete Stochastic Processes

Prereq.: 6.041 or 6.431 or 18.313
G (Spring)
3-0-9 H-LEVEL Grad Credit

Review of probability and laws of large numbers; Poisson counting process and renewal processes; Markov chains (including Markov decision theory), branching processes, birth-death processes, and semi-Markov processes; continuous-time Markov chains and reversibility; random walks, martingales, and large deviations; applications from queueing, communication, control, and operations research.
*R. G. Gallager, R. C. Larson*

### 6.263 Data-Communication Networks

Prereq.: 6.041 or 18.313
G (Fall)
3-0-9 H-LEVEL Grad Credit

Modeling of the control processes in conventional and high-speed data communication networks. Develops and utilizes elementary concepts from queueing theory, algorithms, linear and nonlinear programming to study the problems of line and network protocols, distributed algorithms, quasi-static and dynamic routing, congestion control, deadlock prevention. Treats local and wide-area networks, and high-speed electronic and optical networks.
*D. P. Bertsekas*

### 6.281J Logistical and Transportation Planning Methods

(Same subject as 1.203J, 11.526J, 13.665J, 15.073J, 16.76J)
Prereq.: 6.431, 15.075
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 1.203J.
*R. C. Larson, A. I. Barnett, A. R. Odoni*

### 6.291 Seminar in Systems, Communications, and Control Research

Prereq.: Permission of instructor
G (Fall, Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

A seminar dealing with advanced topics in systems, communications, control, and signal processing. Selected topics according to student and instructor interest. See instructor for specific topics to be offered in a particular term.
*S. K. Mitter*

## Electronics, Computers, and Systems

### 6.301 Solid-State Circuits

Prereq.: 6.012
G (Spring)
4-2-6

Analysis and design of transistor circuits, based directly on the semiconductor physics and transistor circuit models developed in 6.012. High-frequency and low-frequency design calculations and simulation of multistage transistor circuits. Trans-linear circuits. The charge-control model. Introduction to operational-amplifier design and application. Some previous laboratory experience assumed. 4 Engineering Design Points.
*J. K. Roberge, H-S. Lee*

### 6.302 Feedback Systems

Prereq.: 6.003 or 2.003 or 16.040
U (Fall)
4-2-6

Introduction to design of feedback systems. Properties and advantages of feedback systems. Time-domain and frequency-domain performance measures. Stability and degree of stability. Nyquist criterion. Frequency-domain design. Root locus method. Compensation techniques. Application to a wide variety of physical systems. Some previous laboratory experience with electronic systems is assumed (e.g., 6.002 or 6.071 or 16.040). 4 Engineering Design Points.
*J. K. Roberge*

### 6.312 Acoustics

Prereq.: 6.002
U (Fall)
5-0-7

Sound generation and propagation in elastic media. Simple sources and arrays of sources. Derivation of lumped parameter acoustical elements and circuits from solutions of wave equations. Radiation impedance. Conversion among acoustical, electrical, and mechanical energy. Modeling and analysis of electroacoustical devices such as microphones and loudspeakers. Sound in rooms. Interaction of sound and humans.
*A. G. Bose*

### 6.313 Contemporary Computer Design

Prereq.: 6.004
U (Fall)
3-0-9

Computer arithmetic; high-speed logic design and packaging; clocking strategies; pipelined computer techniques; microprogramming vs simple instruction sets; cache and paging design; datatyping, hardware support for garbage collection; MIMD/SIMD parallel computers; interprocessor communications technologies. 2 Engineering Design Points.
*T. F. Knight, Jr.*

### 6.331 Advanced Circuit Techniques

Prereq.: 6.301, 6.302
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-2-7 H-LEVEL Grad Credit

Following a brief classroom discussion of relevant principles, each student completes the paper design of several advanced circuits such as multiplexers, sample-and-holds, gain-controlled amplifiers, analog multipliers, digital-to-analog or analog-to-digital converters, and power amplifiers. One of each student's designs may be presented to the class, and one may be built and evaluated. Associated laboratory emphasizing the use of modern analog building blocks. Enrollment limited. Permission of instructor required. Alternate years. 12 Engineering Design Points.
*J. K. Roberge*

### 6.333 Electronic Circuits

Prereq.: 6.003, 6.012
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Design, analysis, and simulation of linear and nonlinear circuits including application of circuit methods to modeling and analysis of physical systems. Topics: direct, recursive, and iterative analysis of lumped and distributed circuits; computer modeling and simulation of electromagnetic fields and forces; analog and digital signal processing; power electronic systems; feedback control of nonlinear and unstable systems; oscillatory and chaotic circuits; sensitivity and noise. Emphasis on developing circuit intuition. Alternate years.
*R. D. Thornton*

### 6.334 Power Electronics

Prereq.: 6.012, 6.013
G (Spring)
3-0-9 H-LEVEL Grad Credit

The application of electronics to energy conversion and control; phase-controlled rectifier/inverter circuits, dc/dc converters, high frequency inverters, and motion control systems. Characteristics of power semiconductor devices: diodes, bipolar and field effect transistors, and thyristors. Modeling, analysis, and control techniques. Magnetic circuits. Numerous application examples.
*J. G. Kassakian, M. F. Schlecht*

### 6.335 Fundamental Theory of Nonlinear Networks

Prereq.: 6.011, 6.012
G (Fall)
3-0-9 H-LEVEL Grad Credit

Rigorous basis for circuit theory and relation to engineering intuition. Network topology: graph theory, Tellegen's theorem, colored branch theorem. Linear networks: impedance matching, reciprocity, natural frequencies, sensitivity to element values. Nonlinear resistive networks: linearization, passivity, reciprocity, Gilbert translinear principle. Nonlinear dynamic networks: phase-plane analysis, nonlinear differential equations, multiple time scales. Application to analog circuits for machine vision. Alternate years.
*J. L. Wyatt, Jr.*

### 6.336J Introduction to Numerical Algorithms

(Same subject as 18.338J)
Prereq.: 18.03, 18.06 or equivalents
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Introduction to theoretical and practical aspects of numerical algorithms, emphasizing broadly applicable techniques. Application examples: problems in circuit analysis; electrostatics; mechanical elastostatics. Topics: equation formulation approaches; linear system solution by sparse direct factorization; nonlinear equation solution; Newton's method; issues of A-stability; local and global error analysis; solution of elliptic differential and integral equations; FFT and multipole-accelerated algorithms, more. Alternate years.
*J. K. White, A. Edelman*

### 6.337J Numerical Methods of Applied Mathematics I

(New)

(Same subject as 18.335J)
Prereq.: 18.03, 18.06 or equivalent
G (Fall)
3-0-9 H-LEVEL Grad Credit

IEEE-standard, iterative and direct linear system solution methods, eigendecomposition and model-order reduction, fast Fourier transforms, multigrid, wavelets and other multiresolution methods, matrix sparsification.
*J. K. White, A. Edelman*

### 6.338J Parallel Scientific Computing

(New)

(Same subject as 18.337J)
Prereq.: 18.06 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Advanced interdisciplinary introduction to modern scientific computing on parallel supercomputers. Numerical topics include dense and sparse linear algebra, N-body problems, and Fourier transforms. Geometrical topics include partitioning and mesh generation. Other topics include architectures and software systems with hands-on emphasis on understanding the realities and myths of what is possible on the world's fastest machines.
*J. K. White, A. Edelman*

### 6.341 Discrete-Time Signal Processing

Prereq.: 6.011; 18.075 or 18.04
G (Fall, Spring)
4-0-8 H-LEVEL Grad Credit

Representation, analysis, and design of discrete time signals and systems. Review of Z-transforms, discrete-time Fourier transforms, difference equations. All-pass and minimum phase systems. Effects of group delay. DT processing of continuous-time signals. Decimation and interpolation. Flowgraph structures for DT systems. Time- and frequency-domain design techniques for recursive (IIR) and nonrecursive (FIR) filters, discrete Fourier transform, FFT algorithm, Hilbert transforms, various applications.
*A. V. Oppenheim*

### 6.343 Digital Speech Processing

Prereq.: 6.341
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
4-0-8 H-LEVEL Grad Credit

Application of digital signal processing to speech signals. Acoustic theories of speech production leading to time- and frequency-domain models. Speech analysis-synthesis techniques based on the spectrogram, linear prediction, homomorphic, filter bank, and sinusoidal representations. Speech coding using scalar and vector quantization. Time-scale and pitch modification; speech restoration; speaker separation. Pitch estimation; frequency modulation models; constant-Q analysis. Application to music analysis-synthesis. Alternate years.
*T. F. Quatieri*

### 6.344 Two-Dimensional Signal and Image Processing

Prereq.: 6.341
G (Spring)
3-0-9 H-LEVEL Grad Credit

Representation, analysis, and design of two-dimensional signals and systems. Two-dimensional Fourier transform, z-transform, discrete Fourier transform, and fast Fourier transform algorithms. Image processing basics. Image enhancement. Image restoration. Image coding. Advanced television systems.
*J. S. Lim*

### 6.345 Automatic Speech Recognition

Prereq.: 6.341; 6.041 or 6.431
G (Spring)
3-1-8 H-LEVEL Grad Credit

Graduate-level introduction to automatic speech recognition. Provides relevant background in acoustic theory of speech production, properties of speech sounds, signal representation, acoustic modeling, pattern classification, search algorithms, stochastic modeling techniques (including hidden Markov modeling), and language modeling. Examines approaches of state-of-the-art speech recognition systems. Enrollment limited. Alternate years. 4 Engineering Design Points.
*V. W. Zue, J. R. Glass*

### 6.371 Introduction to VLSI Systems

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

Provides background in integrated devices, circuits, and digital subsystems needed for design and implementation of integrated systems. Design methodology, use of ratioed design rules and library modules, symbolic layout languages, computer-aided design techniques. Students required to complete, through layout, the design of a digital subsystem in NMOS or CMOS. Selected projects form a multi-project chip set, leading to wafers available after the end of the term for packaging and testing by the student. Limited enrollment. 8 Engineering Design Points.
*J. Allen*

### 6.372 Design and Analysis of VLSI Circuits

Prereq.: 6.371
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

MOS device parameters, design rules, and fabrication from a circuit design perspective. Physics of devices and interconnect. Noise margins, worst-case design. Circuit design of high-speed gates. Analog aspects of digital design. Clocking. System level issues in VLSI design. Alternate years. 2 Engineering Design Points.
*T. F. Knight, Jr.*

### 6.373 Computer-Aided Design of Integrated Circuits

Prereq.: 6.004
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Theoretical, algorithmic, and practical aspects of the development of computer-aided design tools for VLSI design. Automated synthesis at the logic, layout, and architectural levels. Testing of VLSI circuits, formal verification and design-for-testability methods, and interaction between synthesis and testability of VLSI systems. Alternate years. 2 Engineering Design Points.
*S. Devadas*

### 6.374 Analysis and Design of Digital Integrated Circuits

(New)

Prereq.: 6.012 or 6.371
G (Fall)
3-3-6 H-LEVEL Grad Credit

Device and circuit level optimization of digital building blocks. MOS and bipolar device and parasitic models and second order effects. Circuit design styles and arithmetic structures. Estimation and minimization of energy consumption. Interconnect models and parasitics; driver design; timing issues (clock skew, self-timed circuits, etc.). Memory architectures, circuits (sense amplifiers) and devices. Extensive use of circuit layout and SPICE in design projects and software labs. 4 Engineering Design Points.
*A. P. Chandrakasan*

## Probabilistic Systems and Communication

### 6.430J Engineering Probability and Statistics

(Same subject as 3.81J, 15.064J)
Prereq.: 18.02
G (Summer)
4-0-8 H-LEVEL Grad Credit

Modeling and analysis of uncertainty. Random variables, transforms, simple random processes and their probability laws. Probability assessment and decision analysis. Limit theorems. Introduction to experimental design. Regression and basic statistical procedures pertinent to manufacturing and quality control. Primarily intended for students in the Leaders for Manufacturing Program; others may consult instructor.
*A. W. Drake*

### 6.431 Applied Probability

(Subject meets with 6.041)
Prereq.: 18.02
G (Fall, Spring)
4-0-8

Meets with undergraduate subject 6.041. Requires the completion of additional advanced home problems. See description under subject 6.041.
*A. W. Drake*

### 6.432 Stochastic Processes, Detection, and Estimation

Prereq.: 6.011; 18.06
G (Fall, Spring)
4-0-8 H-LEVEL Grad Credit

Fundamentals of detection and estimation for signal processing, communications, and control. Vector spaces of random variables. Bayesian and Neyman-Pearson hypothesis testing. Bayesian and nonrandom parameter estimation. Minimum-variance unbiased estimators and the Cramer-Rao bounds. Representations for stochastic processes; shaping and whitening filters; Karhunen-Loeve expansions. Detection and estimation from waveform observations. Advanced topics; linear prediction and spectral estimation; Wiener and Kalman filters.
*A. S. Willsky, G. W. Wornell*

### 6.433 Recursive Estimation

Prereq.: 6.241, 6.432
G (Spring)
3-0-9 H-LEVEL Grad Credit

State-space based theory of dynamic estimation in discrete and continuous time. Linear state-space models driven by white noise. Kalman filter and its properties. Implementation issues, including the solution of the Riccati equation, the square-root filter, and efficient algorithms for the Kalman gain. Optimal smoothing for linear systems. Nonlinear filtering and the extended and second-order Kalman filters.
*A. S. Willsky*

### 6.435 System Identification

Prereq.: 6.241, 6.432
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Mathematical models of systems from observations of their behavior. Time series, state-space, input-output models. Model structures, parametrization, identifiability. Non-parametric methods. Prediction error methods for parameter estimation, convergence, consistency, asymptotic distribution. Relations to maximum likelihood estimation. Recursive estimation; relation to Kalman filters; structure determination; order estimation; Akaike criterion; bounded but unknown noise models. Robustness, practical issues. Alternate years.
*M. A. Dahleh, S. K. Mitter*

### 6.441 Transmission of Information

Prereq.: 6.262 or 6.432 or 6.431
G (Spring)
3-0-9 H-LEVEL Grad Credit

Introduction to the quantitative theory of information and its applications to reliable, efficient communication systems. Mathematical definition and properties of information. The source coding theorem. Lossless compression of data, including adaptive compression for unknown source statistics. Noisy communication channels, the data processing theorem, and fundamental limits on decoding error. Introduction to algebraic and convolutional error correction coding techniques.
*R. G. Gallager, M. D. Trott*

### 6.451 Principles of Communication

Prereq.: 6.011
G (Fall)
3-0-9 H-LEVEL Grad Credit

Fundamental principles underlying the digital transmission of information over linear Gaussian channels. Nyquist theory; modulation; signal space concepts; optimum detection; signal set design; introduction to coding for Euclidean-space channel; the Viterbi algorithm; intersymbol interference and adaptive equalization; equalization via precoding; approaching channel capacity of linear Gaussian channels. Current topics.
*R. G. Gallager*

### 6.455J Sonar, Radar and Seismic Signal Processing I

(Same subject as 13.741J, 12.518J)
Prereq.: 2.02 or 2.003 or 6.003, 6.041, 18.075 or 18.085
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 13.741J.
*A. B. Baggeroer, J. R. Fricke*

### 6.456J Sonar, Radar and Seismic Signal Processing II

(Same subject as 13.742J, 12.519J)
Prereq.: 13.741J
G (Spring)
3-1-8 H-LEVEL Grad Credit

See description under subject 13.742J.
*A. B. Baggeroer, J. R. Fricke*

## Bioelectrical Engineering

### 6.501 Sound, Speech, Hearing

Prereq.: 6.003
Acad Year 1996-97: U (Fall)
Acad Year 1997-98: **Not offered**
3-0-9

Introduces the physical, physiological, and psychological bases of auditory communication. Sound propagation in tubes, sound radiation, properties of neural and muscular elements, the vocal tract and speech generation, signal transmission in the auditory system, perception of attributes of speech and speechlike sounds, and the linguistic units that underlie speech events. Disorders of human communication. Alternate years.
*K. N. Stevens, L. D. Braida*

### 6.521J Quantitative Physiology: Cells and Tissues

(Subject meets with 6.021J, 2.791J, 2.794J, HST.541J)
Prereq.: 2.003 or 6.002 or 6.071 or 10.301; 8.02, 18.03
G (Fall)
5-2-5

Meets with undergraduate subject 6.021J. Requires the completion of more advanced home problems and/or an additional project. See description under subject 6.021J.
*T. F. Weiss, D. M. Freeman*

### 6.522J Quantitative Physiology: Organ Transport Systems

(Subject meets with 6.022J, 2.792J, 2.796J, HST.542J)
Prereq.: 2.006 or 6.013; *6.021J*
G (Spring)
4-2-6

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

### 6.541J Speech Communication

(Same subject as 24.968J, HST.710J)
Prereq.: Permission of instructor
G (Spring)
3-1-8 H-LEVEL Grad Credit

Survey of structural properties of natural languages, with special emphasis on the sound pattern. Physiology of speech production, articulatory phonetics. Acoustical theory of speech production; acoustical and articulatory descriptions of phonetic features. Perception of speech: the auditory capabilities of humans; evidence for perceptual correlates of phonetic categories. Applications to recognition and generation of speech by machine. Recommended prerequisite: mathematical background equivalent to 6.003.
*K. N. Stevens, S. J. Keyser*

### 6.542J Laboratory on the Physiology, Acoustics, and Perception of Speech

(Same subject as 24.966J, HST.712J)
Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
2-2-8 H-LEVEL Grad Credit

Experimental investigations of speech processes. Topics: a) measurement of articulatory movements, b) measurements of pressure and volume velocity, c) computer-aided waveform analysis and spectral analysis of speech, d) synthesis of speech, e) perception and discrimination of speechlike sounds, f) speech prosody, g) hidden Markov models for speech recognition, and other topics. Recommended prerequisites: 6.501, 6.002 or 18.03. Alternate years. 4 Engineering Design Points.
*K. N. Stevens, J. S. Perkell, S. Shattuck-Hufnagel*

### 6.551J Acoustics of Speech and Hearing

(Same subject as HST.714J)
Prereq.: 8.03 and 6.003 or permission of instructor
G (Fall)
4-2-6 H-LEVEL Grad Credit

Electric-acoustic analogies. Review of basic ideas of circuit theory; natural frequencies, two-ports, reciprocity, energy, and power. Laws of acoustics. Waves in one dimension. Acoustic impedance. Natural frequencies in tubes. Lumped approximations. Losses, non-uniform plane waves, horns. Room acoustics. Sound sources and microphones. Concepts applied to speech production and hearing. Laboratories demonstrate measurement methods, data presentation, and tests of theory. 4 Engineering Design Points.
*W. T. Peake, J. J. Rosowski, W. M. Rabinowitz, K. N. Stevens*

### 6.552J Signal Processing by the Auditory System: Perception

(Same subject as HST.716J)
Prereq.: 6.003; 6.041 or 6.431 and permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit

Studies behavioral aspects of human hearing in relation to current physiological knowledge. Examines performance in processing information from acoustic stimuli. Correlations between behavior and physiology, reflecting the tono-topic organization and stochastic responses of the auditory system. Mathematical models of psychophysical relations, incorporating quantitative knowledge of physiological transformations by the peripheral auditory system. Discusses related research on diagnosis and aids for partially deaf.
*L. D. Braida*

### 6.555J Biomedical Signal and Image Processing

(Same subject as HST.582J, 16.456J)
Prereq.: 6.003 or 2.003 or 18.085
G (Spring)
3-6-3 H-LEVEL Grad Credit

See description under subject HST.582J.
*L. D. Braida, B. Delgutte, A. Dobrzeniecki, J. Greenberg*

### 6.561J Fields, Forces, and Flows: Background for Physiology

(Same subject as 2.795J, HST.544J)
Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Conduction, diffusion, convection in electrolytes; fields in heterogeneous media; electrical double layers; Maxwell stress tensor and electrical forces in physiological systems. Fluid and solid continua: equations of motion useful for porous, hydrated biological tissues. Case studies: membrane transport; electrode interfaces; electrical, mechanical, and chemical transduction in tissues; electrophoretic, electroosmotic flows; diffusion/reaction; ECG. Electromechanical and physicochemical interactions in biomaterials and cells; orthopaedic, cardiovascular, and other clinical examples.
*A. J. Grodzinsky*

### 6.566J Biosensors, Signal Processing, and Biomedical Applications

(Same subject as HST.585J)
Prereq.: Permission of instructor
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-3-6 H-LEVEL Grad Credit

Alternate years. 6 Engineering Design Points. See description under subject HST.585J.
*S. K. Burns, J. C. Weaver*

## Electrodynamics

### 6.601 Fields, Forces, and Motion

Prereq.: 6.013
G (Fall)
3-0-9

Electromechanical interactions in lumped-parameter and continuum systems. Integral and differential electromagnetic laws, including motion. Lumped electrical and mechanical elements: thermodynamics of discrete electromechanical coupling, equations of motion. Synchronous and induction rotating machines. Linear and nonlinear transducers, transient and steady-state dynamics; electromechanical time constants. Field transformations, dc rotating machines, magnetic diffusion and charge relaxation in moving conductors. Electromagnetic force densities and stress tensors.
*J. H. Lang*

### 6.630 Electromagnetic Waves

Prereq.: 8.02 or 6.013 or 6.014
G (Fall)
3-0-9 H-LEVEL Grad Credit

An introductory subject on electromagnetic waves. Topics: polarization, Stokes parameters, Poincaré sphere, gyrotropic media, uniaxial media, phase matching, layered media, dielectric waveguides, metallic waveguides and resonators, Cerenkov radiation, Hertzian dipole, equivalence principle, and reciprocity. Examples deal with propagation, guidance, and radiation of electromagnetic waves.
*J. A. Kong*

### 6.631 Optics and Optical Electronics

Prereq.: 6.014 or 8.07
G (Fall)
3-0-9 H-LEVEL Grad Credit

A first-year graduate subject on fundamental concepts and techniques of modern optics and quantum electronics. Review of Maxwell's equations and the vector properties of light. Interference and interferometers. Temporal and spatial coherence. Scalar diffraction theory. Propagation of spherical and Gaussian-spherical beams. Thin film and "fiber" waveguides. Device applications of electrooptic effect and nonlinear optics.
*J. G. Fujimoto*

### 6.632 Electromagnetic Wave Theory

Prereq.: 6.013 or 6.014 or 6.630
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

A first-year graduate subject on electromagnetic wave theory, emphasizing mathematical approaches, problem solving, and physical interpretation. Topics include equivalence principle, duality and complementarity, Huygens' principle, Fresnel and Fraunhofer diffraction, random media, effective permittivities, dyadic Green's functions, Lorentz transformation, Maxwell-Minkowski theory. Examples deal with limiting cases of Maxwell's theory and diffraction and scattering of electromagnetic waves. Alternate years.
*J. A. Kong*

### 6.633 Electrodynamics of Waves, Media, and Interactions

Prereq.: 6.014 or 8.07; 18.04 or *18.075*
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Wave propagation in media with temporal and spatial dispersion; pulse propagation and Green's function analysis. Linear stability theory; absolute and convective instabilities. Energy, momentum, and their flows associated with small-amplitude wave propagation in passive and active media. Geometric optics and mode conversion in inhomogeneous media. Linear and nonlinear coupling of modes in stable and unstable systems. Nonlinear dynamics of order and chaos; solitons and intrinsic stochasticity. Alternate years.
*A. Bers*

### 6.634 Nonlinear Optics

Prereq.: 6.014, 6.017
G (Spring)
3-0-9 H-LEVEL Grad Credit

Nonlinear optical phenomena, emphasizing applications, techniques, and devices. Nonlinear polarization: harmonic generation, frequency conversion, optical Kerr effect, self-phase modulation, wavefront conjugation. Pulse propagation in nonlinear media. Applications to fiber optics. Nonlinear laser spectroscopy. Picosecond and femtosecond measurement techniques.
*E. P. Ippen, J. G. Fujimoto*

### 6.635 Topics in Electromagnetism

Prereq.: 6.014 or 6.630 or 8.07
G (Spring)
3-0-9 H-LEVEL Grad Credit

Material covered differs from year to year according to interest of students and instructor in charge. Typical topics include electrodynamics of moving media, waves in dispersive media, microstrip integrated circuits, quantum optics, remote sensing, radiative transfer theory and random media.
*J. A. Kong*

### 6.637 Optical Information Processing

Prereq.: 6.003, 6.014
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Systems, algorithms, devices, and applications for optical information processing. Topics: coherent and incoherent optical processors; space-and-time-integrating correlators; space-variant processors; white-light processors; digital optical processors; matrix-algebraic processors; symbolic optical processors; optical neural networks; adaptive optics; acoustooptic, electrooptic, and photorefractive spatial light modulators; limitations of optical computers. Alternate years.
*C. Warde*

### 6.641 Microwave Circuits

Prereq.: 6.014
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Electromagnetic wave propagation on uniform and periodic structures, waveguide, stripline, and microstrip. Surface Acoustic Wave (SAW) and magnetic resonance devices. Equivalent circuit representations for apertures and obstacles. Multiport junctions. Non-reciprocal ferrite devices. Cavity and solid state resonators; filters. Perturbation theory. Alternate years.
*F. R. Morgenthaler*

### 6.651J Introduction to Plasma Physics I

(Same subject as 8.613J, 22.611J)
Prereq.: 6.014 or 8.07; 18.04 or *18.075*
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 8.613J.
*A. Bers, B. Coppi*

### 6.652J Introduction to Plasma Physics II

(Same subject as 8.614J, 22.612J)
Prereq.: 6.651J or 8.613J or 22.611J
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 8.614J.
*P. Catto*

### 6.661 Receivers, Antennas, and Signals

Prereq.: 6.014 or 8.03, 6.003 or 16.040 or 2.004
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Detection and measurement of radio and optical signals encountered in communications, astronomy, remote sensing, instrumentation, and radar. Statistical analysis of signal processing systems, including radiometers, spectrometers, interferometers, and digital correlation systems. Matched filters and ambiguity functions. Communications channel performance. Measurement of random electromagnetic fields. Angular filtering properties of antennas, interferometers, and aperture synthesis systems. Radiative transfer and parameter estimation. Alternate years.
*D. H. Staelin*

### 6.671 Continuum Electromechanics I

Prereq.: 6.013
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Quasistatic electric and magnetic field dynamics. Transfer relations as an approach to field descriptions. Electromagnetic forces, force densities, and stress tensors, including magnetization and polarization. Classification of energy-conversion processes. Charge migration and relaxation, and magnetic diffusion and induction interactions with material motion. Introduction to electromechanics of fluids and solids. Temporal and spatial modes. Spectral numerical techniques. Method of characteristics. Varied applications. Alternate years.
*M. Zahn*

### 6.672 Continuum Electromechanics II

Prereq.: 6.671
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Laws, approximations, and relations of continuum mechanics. Mechanical and electromechanical transfer relations. Statics and dynamics of electromechanical systems having a static equilibrium. Electromechanical flows. Field coupling with thermal and molecular diffusion. Electrokinetics. Streaming interactions. Applications to materials processing, magnetohydrodynamic and electrohydrodynamic pumps and generators, physiochemical systems, heat transfer, continuum feedback control, electron beam devices, and plasma dynamics. Emphasis on microfabricated systems. Alternate years.
*M. Zahn*

**6.673 Introduction to Numerical Simulation in Electrical Engineering**

Prereq.: 6.012 or 6.013
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

Selection of a simulation model and physical approximations. Solution of nonlinear coupled PDEs in 1-D through finite difference and finite element methods, Newton's method, and variants. Finite difference and finite element methods in 2-D and sparse matrix methods emphasizing conjugate gradient algorithms. Semiconductor devices used as primary examples; additional examples drawn from E&M modeling, nonlinear pulse propagation, and laser physics. Alternate years.
*P. L. Hagelstein*

**6.683J Operation and Planning of Electric Power**

(Same subject as TPP.61J)
Prereq.: 6.061 or 6.013; 15.011
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-9 H-LEVEL Grad Credit

Focus on worldwide changes in power systems from generation technology to network operation, including significant customer and private generation. Topics include evaluation of new technologies in system control; conservation and load management; supply; system economics; rate setting; deregulation; customer response to new rates. Electrical and economic analysis of power transfers: wheeling. Alternate years.
*M. D. Ilic, R. D. Tabors*

**6.685 Electric Machines**

Prereq.: 6.013 and permission of instructor
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Treatment of transformers, electromechanical transducers, rotating and linear electric machines. Lumped-parameter electromechanics of interaction. Consideration of the basic machine types: dc, induction, synchronous. Development of device characteristics: energy conversion density, efficiency; and of system interaction characteristics: regulation, stability, controllability, and response. Problems taken from current research. Alternate years.
*J. L. Kirtley, Jr.*

**6.686 Advanced Power Systems I**

Prereq.: 6.002 or equivalent
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Basic components of power systems and function in interconnected systems: fast dynamics (synchronous generators and their voltage regulation); slow-speed dynamics (turbines and their governor control); networks and consumers; long-term dynamics (boilers, nuclear reactors, and local control). Principles of real-time monitoring and control of the interconnected system: automatic generation control and reactive flow control. Leads to research opportunities. Recommended corequisite: 6.241. Alternate years.
*M. D. Ilic*

**6.688J Strategic Analysis for Environmental Policy Planning, Design, and Implementation**

(Same subject as 1.141J, 3.563J, 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*

**6.689 Seminar on Power System Modeling, Dynamics, and Control**
(New)

Prereq.: 6.241 or permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Seminar on advanced topics in power systems. Content varies by semester. Possible topics: control and coordination of large-scale electric power systems with physical and economic constraints imposed by a competitive industry; estimation and control of electrical machine systems; application of techniques for nonlinear system analysis to study dynamics occurring in electrical energy systems. See instructor for details concerning material for a particular semester.
*M. D. Ilic, B. C. Lesieutre, G. C. Verghese*

## Solid-State Materials and Devices

**6.720 Integrated Microelectronic Devices**

Prereq.: 6.012 or equivalent
G (Fall)
4-0-8

The physics of semiconductor devices for silicon integrated circuit applications. Topics: semiconductor fundamentals, p-n junction, metal-oxide semiconductor structure, metal-semiconductor junction, MOS field-effect transistor, and bipolar junction transistor. Emphasis on building professional device models and developing physical intuition through the use of energy band diagrams. First- and second-order effects discussed. Issues in modern device scaling outlined. 2 Engineering Design points.
*J. A. del Alamo*

**6.728 Applied Quantum and Statistical Physics**
(Revised Units)

Prereq.: 6.003, 18.06
G (Fall)
4-0-8

Elementary quantum mechanics and statistical physics. Introduces applied quantum physics. Emphasizes experimental basis for quantum mechanics. Applies Schrodinger's equation to the free particle, tunneling, the harmonic oscillator, and hydrogen atom. Variational methods. Elementary statistical physics; Fermi-Dirac, Bose-Einstein, and Boltzmann distribution functions. Simple models for metals, semiconductors, and devices such as electron microscopes, scanning tunneling microscope, thermonic emitters, atomic force microscope, more.
*S. D. Senturia, P. L. Hagelstein*

**6.730 Physics for Solid-State Applications**

Prereq.: 6.013 or 6.014, 6.728
G (Spring)
5-0-7 H-LEVEL Grad Credit

Classical and quantum models of electrons and lattice vibrations in solids, emphasizing physical models for electronic transport and heat capacity. Crystal lattices, energy band structures in 3D, calculation of 1D and 2D band structures, effective mass theorem, semiclassical equations of motion, and impurity states in semiconductors. Band structure and transport properties of selected semiconductors. Connection of quantum theory of solids with quasifermi levels and Boltzmann transport used in device modeling.
*T. P. Orlando, S. D. Senturia*

### 6.732 Physics of Solids

Prereq.: 6.730 or 8.231
G (Fall)
4-0-8 H-LEVEL Grad Credit

Continuation of 6.730 emphasizing applications-related physical issues in solids. Topics: electronic structure and energy band diagrams of semiconductors, metals, and insulators; Fermi surfaces; dynamics of electrons; classical diffusive transport phenomena such as electrical and thermal conduction and thermoelectric phenomena; quantum transport in tunnel ballistic devices; optical properties of metals, semiconductors, and insulators; photon-lattice interactions; magnetic properties of solids; magneto-oscillatory phenomena; quantum Hall effect; superconducting phenomena and simple models.
*Q. Hu, M. S. Dresselhaus*

### 6.734J Application of Group Theory to the Physics of Solids

(Same subject as 8.510J)
Prereq.: 6.732 or 8.231
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Group theory techniques: mathematical background, representation theory, character tables, basis functions, point groups, space groups, double groups, time reversal symmetry. Applications: crystal field structure, selection rules, directed valence and bonds, molecular vibrations, group of the wave vector with application to energy bands, lattice modes. Alternate years.
*M. S. Dresselhaus*

### 6.735J Modern Topics in Solid State Physics

(Same subject as 8.532J)
Prereq.: 6.732 or 8.231
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-9 H-LEVEL Grad Credit

Alternate years. See description under subject 8.532J.
*M. S. Dresselhaus*

### 6.751 Quantum Electronics

Prereq.: 6.728 or 8.05
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
3-0-9 H-LEVEL Grad Credit

The quantum theory of light. Basic phenomena of quantum electronics, including development of background quantum mechanics and optical properties of solids. Quantization of electromagnetic field and spontaneous plus stimulated optical transitions between energy levels. Resonant processes: electric dipole transitions, absorption, dispersion, saturation. Photon optics and counting. Coherence. The laser and its operating characteristics. Rate equations, optical pumping, Q-switching, mode locking. Resonance fluorescence, light scattering. Alternate years.
*G. W. Pratt, Jr.*

### 6.763 Applied Superconductivity

Prereq.: 6.013 or 8.07
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Phenomenological approach to superconductivity, surveying large-scale and small-scale applications. Electrodynamics of superconductors, London's model, flux quantization. Type II superconductors, upper critical fields, pinning, critical state model. Josephson Junctions and superconducting quantum devices, equivalent circuits and analogs, computers. Brief overview of superconducting materials and microscopic theory. Some background in solid-state physics helpful. Alternate years.
*T. P. Orlando*

### 6.772 Compound Semiconductor Devices

Prereq.: 6.720, 6.730
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Spring)
4-0-8 H-LEVEL Grad Credit

Physics, modeling, application, and technology of compound semiconductors (primarily III-Vs) in electronic, optoelectronic, and photonic devices and integrated circuits. Topics: properties, preparation, and processing of compound semiconductors; theory and practice of heterojunctions, quantum structures, and pseudomorphic strained layers; metal-semiconductor field effect transistors (MESFETs); heterojunction field effect transistors (HFETs) and bipolar transistors (HBTs); and optoelectronic devices. Alternate years.
*C. G. Fonstad, Jr.*

### 6.774 Physics of Microelectronic Fabrication

Prereq.: 6.152J or equivalent
G (Fall)
3-0-9 H-LEVEL Grad Credit

Fundamental principles of the processes used in the fabrication of silicon monolithic integrated circuits. Physical models of bulk crystal growth, thermal oxidation, solid-state diffusion, ion implantation, epitaxial deposition, chemical vapor deposition, and physical vapor deposition. Refractory metal silicides, plasma and reactive ion etching, rapid thermal processing. Process modeling and simulation. Technological limitations on integrated circuit design and fabrication. VLSI fundamentals.
*L. R. Reif*

### 6.775 Design of Analog MOS LSI

Prereq.: 6.301
G (Fall)
3-0-9 H-LEVEL Grad Credit

A detailed exposition of the principles involved in designing analog circuits in MOS LSI. Device physics, small signal and large signal models. Biasing. Basic circuit building blocks. Operational amplifier design. Large signal considerations. Principles of switched capacitor networks. Applications: fully integrated filters, comparators, A/D and D/A converters, other signal processing circuits. A comprehensive design project is a required part of the subject. 4 Engineering Design Points.
*H. S. Lee, C. G. Sodini*

### 6.776J Plasma Processing in Integrated Circuit Fabrication

(Same subject as 10.582J)
Prereq.: Permission of instructor
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Studies glow discharge properties and processes as applied to integrated circuit fabrication. The physics and chemistry of nonequilibrium plasmas. Emphasizes the plasma kinetics and plasma-surface interactions. Extensively reviews plasma etching processes, sputter deposition, and plasma enhanced chemical vapor deposition for the fabrication of VLSI devices. Alternate years.
*L. R. Reif, H. H. Sawin*

### 6.781 Submicrometer and Nanometer Technology

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

Surveys techniques to fabricate and analyze submicrometer and nanometer structures, with applications. Reviews optical and electron microscopy. Surface characterization, preparation, and measurement techniques. Resist technology. Optical projection, holographic, X-ray, ion, and electron lithography. Aqueous, ion, and plasma etching techniques. Lift-off and electroplating. Ion implantation. Applications in microelectronics, optoelectronics, and quantum-effect electronics. Undergraduates with permission of instructor.
*H. I. Smith*

### 6.791 Special Topics in the Solid State and Its Application

Prereq.: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

### 6.792 Special Topics in the Solid State and Its Application

Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Primarily for those interested in research on solid-state materials and devices for electrical and electronic applications. Topics and staff to be announced each term. Given independently or sequentially as circumstances require.
*F. R. Morgenthaler*

## Computer Science

### 6.801 Machine Vision

Prereq.: 6.003 or permission of instructor
U (Fall)
3-0-9

Deriving a symbolic description of the environment from an image. Understanding physics of image formation. Image analysis as an inversion problem. Binary image processing and filtering of images as preprocessing steps. Recovering shape, lightness, orientation, and motion. Using constraints to reduce the ambiguity. Photometric stereo and extended Gaussian sphere. Applications to robotics; intelligent interaction of machines with their environment.
*B. K. P. Horn*

### 6.805J Ethics and the Law on the Electronic Frontier

(Same subject as STS.085J)
Prereq.: —
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: U (Fall)
3-0-9 HASS

Studies the growth of computer and communications technology and the new legal and ethical challenges that reflect tensions between individual rights and societal needs. Topics: computer crime; intellectual property restrictions on software; encryption, privacy, and national security; academic freedom and free speech. Students meet and question technologists, activists, law enforcement agents, journalists, and legal experts. Extensive use of World Wide Web for readings and other materials. Enrollment limited.
*H. Abelson, M. Fischer*

### 6.821 Programming Languages

Prereq.: Permission of instructor
G (Fall)
4-0-8 H-LEVEL Grad Credit

Principles of functional, imperative, and logic programming languages. Meta-circular interpreters, semantics (operational and denotational), type systems (polymorphism, inference, and abstract types), object oriented programming, modules, multiprocessing. Case studies of contemporary programming languages. Programming experience and background in language implementation required.
*D. K. Gifford*

### 6.823 Computer System Architecture

Prereq.: 6.004 or equivalent
G (Spring)
3-0-9 H-LEVEL Grad Credit

Emphasizes the relationship among technology, hardware organization, and programming systems in the evolution of computer architecture. Technology constraints, machine organization, instruction set architecture, I/O and memory system design, addressing structures and memory management, and their impact on performance and programmability; design and programming of pipelined processors, vector processors, and parallel computers. Assumes an undergraduate knowledge of computer systems. 4 Engineering Design Points.
*Arvind, W. J. Dally*

### 6.826 Principles of Computer Systems

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

An introduction to the basic principles of computer systems with emphasis on the use of rigorous techniques as an aid to understanding and building modern computing systems. Particular attention paid to concurrent and distributed systems. Topics include specification and verification, concurrent algorithms, synchronization mechanisms, naming, communication protocols, replication techniques (including distributed cache management), and principles and algorithms for achieving reliability.
*W. E. Weihl*

### 6.835 Concurrent Systems for Artificial Intelligence

Prereq.: 6.001, 6.034
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-9 H-LEVEL Grad Credit

Concurrent systems and their relationship to artificial intelligence. Organizations as exemplars of highly intelligent parallel systems. Concurrent architectures for artificial intelligence (e.g., Apiary, Connection Machine, and parallel Prolog machines). Incrementally evolving networks of computers. Mathematical models of concurrent systems (e.g., Actor Model, Milner's algebraic model, and Hoare's process model). Alternate years.
*C. E. Hewitt*

### 6.836 Embodied Intelligence
(New)

Prereq.: 6.034, 18.03, 18.06
G (Spring)
3-0-9 H-LEVEL Grad Credit

Studies how to build intelligent systems that have physical embodiment. Examines specific problems, historical solutions, and contemporary research into the area of autonomous embodied systems. Topics: dynamical modeling of agent/environment interaction; neural modeling of perception and action systems; issues in vision and robotics; evolutionary modeling techniques; behavior-based approaches; pre-cognitive and cognitive architectures. Examines problems and sources of simplification presented by a physically embodied system relative to unembodied intelligence.
*R. A. Brooks*

### 6.837 Computer Graphics

Prereq.: 6.046J, 18.06
G (Fall)
3-0-9

Introduction to computer graphics hardware, algorithms, and software. Topics include line generators, affine transformations, line and polygon clipping, splines, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and animation. Substantial programming experience required. 2 Engineering Design Points.
*S. Teller*

### 6.838J Advanced Topics in Computer Graphics
(New)

(Same subject as 4.214J)
Prereq.: 6.837 or 4.210
G (Spring)
3-0-9 H-LEVEL Grad Credit

In-depth study of an active research topic in computer graphics. Topics change each term. Readings from the literature, student presentations, short assignments, and a programming project.
*J. Dorsey*

### 6.840J Theory of Computation

(Same subject as 18.404J)
Prereq.: 6.046J or 6.851
G (Fall)
4-0-8 (H except XVIII)

See description under subject 18.404J.
*S. Goldwasser, M. Karchmer*

### 6.841J Advanced Complexity Theory

(Same subject as 18.405J)
Prereq.: 6.840J
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 18.405J.
*S. Goldwasser, M. Sipser*

### 6.845 Parallel Processing: VLSI and Microarchitecture

Prereq.: 6.823, 6.371
Acad Year 1996-97: G (Fall)
Acad Year 1997-98: **Not offered**
3-5-4 H-LEVEL Grad Credit
Can be repeated for credit

Principles and practical issues in the construction of parallel VLSI computing systems. Trends in VLSI technology. Estimation of area, performance, and power. Parallel-computer mechanisms and machine organization: processing-element architecture and memory-system organization. Communication in VLSI systems: density and timing models; network topology; routing algorithms; flow-control methods. Special-purpose VLSI chips: logic-added memories, sensors, signal and image processors. Class project. Alternate years. 6 Engineering Design Points.
*W. J. Dally*

### 6.846 Parallel Processing: Systems Architecture and Applications

Prereq.: 6.823 or permission of instructor
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Principles in the design and programming of parallel machines. Continuum, particle, and graph applications. Communication and synchronization. Locality in parallel computations. Computational models and parallel computers: dataflow, shared memory, data parallel, message passing. Parallel machine mechanisms such as full-empty synchronization bits, cache coherence, multithreading. Design and performance evaluation of multiprocessor systems. Compilation and runtime technologies: partitioning, placement, scheduling. Substantial project required. Alternate years. 4 Engineering Design Points.
*A. Agarwal*

### 6.847 Dataflow Architecture and Languages

Prereq.: 6.001, 6.004
G (Fall)
3-0-9 H-LEVEL Grad Credit

The dataflow model as a basis for designing parallel systems. Static and dynamic dataflow graphs. Implicit parallel programming using functional languages and their extensions. Higher-order functions, non-strictness, polymorphism. Nondeterministic programming and resource managers. Operational semantics and term rewriting systems. The λ-calculus. Optimizations and static analysis. Compiling into dataflow graphs; partitioning for multi-threaded architectures.
*Arvind*

### 6.848J Theory of Parallel and VLSI Computation

(Same subject as 18.435J)
Prereq.: 6.046J or 6.851
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 18.435J.
*C. E. Leiserson, F. T. Leighton*

### 6.851 Theory of Algorithms

Prereq.: 18.06 or 18.700; 6.042J or 18.310
G (Spring)
3-0-9 H-LEVEL Grad Credit

Techniques for design and analysis of algorithms, emphasizing mathematical methods and proofs. Proof-oriented version of 6.046J/18.410J. Topics: Data structures, sorting, selection, hashing. Solving recurrences. Upper and lower bounds. Dynamic programming. Divide and conquer. Graph algorithms: spanning trees, matching, shortest paths, max flow. Matrix operations. Fast Fourier transform. Integer and polynomial arithmetic. Permutation group membership. Primality testing. Linear programming. Parallel algorithms.
*R. L. Rivest*

### 6.852J Distributed Algorithms

(Same subject as 18.437J)
Prereq.: 6.046J
Acad Year 1996-97: **Not offered**
Acad Year 1997-98: G (Fall)
3-0-9 H-LEVEL Grad Credit

Design and analysis of concurrent algorithms, emphasizing those suitable for use in distributed networks. Process synchronization, allocation of computational resources, distributed consensus, distributed graph algorithms, election of a leader in a network, distributed selection, distributed termination, deadlock detection, concurrency control, communication, clock synchronization. Special consideration given to issues of efficiency and fault tolerance. Formal models for distributed computation. Alternate years.
*N. A. Lynch*

### 6.853 Computer Systems

Prereq.: 6.033
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit

Study and discussion of the literature of computer systems. Subject is designed to help students understand the nature of research in computer systems and to develop a student's ability to judge ideas critically. Computer architecture, networks, operating systems, programming language/system interface, network protocols, file systems, replication, protection, transactions, database systems, computer graphics, user interfaces, and application systems. Alternate years.
*D. K. Gifford*

### 6.854J Advanced Algorithms

(Same subject as 18.415J)
Prereq.: 6.851 or 6.046J; 18.06 or 18.700
G (Fall)
3-0-9 H-LEVEL Grad Credit

See description under subject 18.415J.
*R. L. Rivest, M. Goemans*

### 6.857 Network and Computer Security (New)

Prereq.: 6.033, 6.046J or 6.042J
U (Fall)
3-0-9

Techniques for achieving security in multi-user computer systems and distributed computer systems. Topics: physical security; discretionary and mandatory access control; biometrics; information-flow models of security; covert channels; models for integrity; elementary cryptography; logic of authentication; electronic cash; viruses; firewalls; electronic voting; risk assessment; secure web browsers. Enrollment may be limited.
*R. L. Rivest*

### 6.863J Natural Language and the Computer Representation of Knowledge

(Same subject as 9.611J)
Prereq.: 6.034
G (Spring)
3-3-6 H-LEVEL Grad Credit

Relationship between computer representation of knowledge and the structure of natural language. Emphasizes development of the analytical skills necessary to judge the computational implications of grammatical formalisms, and uses concrete examples to illustrate particular computational issues. Efficient parsing algorithms for context-free grammars; augmented transition network grammars. Question answering systems. Extensive laboratory work on building natural language processing systems. 8 Engineering Design Points.
*R. C. Berwick*

### 6.866 Machine Vision

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

Intensive introduction to the process of generating a symbolic description of the environment from an image. Students expected to attend the 6.801 lectures as well as occasional seminar meetings on special topics. Material presented in 6.801 is supplemented by reading from the literature. Students required to prepare a paper analyzing research in a selected area.
*B. K. P. Horn*

### 6.868J The Society of Mind

(Same subject as MAS.731J)
Prereq.: Must have read *The Society of Mind*, permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit

Introduction to a theory that tries to explain how minds are made from collections of simpler processes. Treats such aspects of thinking as vision, language, learning, reasoning, memory, consciousness, ideals, emotions, and personality. Incorporates ideas from psychology, artificial intelligence, and computer science to resolve theoretical issues such as wholes vs parts, structural vs functional descriptions, declarative vs procedural representations, symbolic vs connectionist models, and logical vs common-sense theories of learning.
*M. Minsky*

### 6.871 Knowledge-Based Applications Systems

Prereq.: 6.034; 6.036 or 6.824
G (Spring)
3-0-9 H-LEVEL Grad Credit

Development of programs containing a significant amount of knowledge about their application domain. Outline: 1) brief review of relevant AI techniques; 2) case studies from a number of application domains, chosen to illustrate principles of system development; 3) discussion of technical issues encountered in building a system, including selection of knowledge representation, knowledge acquisition, etc.; and 4) discussion of current and future research. Hands-on experience in building an expert system (term project). 8 Engineering Design Points.
*R. Davis, P. Szolovits, H. E. Shrobe*

### 6.872 Medical Computing

(New)

Prereq.: 6.034
G (Spring)
3-0-9 H-LEVEL Grad Credit

Analyzes computational needs of clinical medicine, reviews systems and approaches that have been used to support those needs, and examines new technologies. Topics: the nature of clinical data; architecture and design of healthcare information systems; privacy and security issues; medical expert systems; computing support for medical education. Case studies of contemporary systems. Term project using a large pseudonymized clinical dataset integrates classroom topics. 6 Engineering Design Points.
*P. Szolovits*

### 6.875J Cryptography and Cryptanalysis

(Same subject as 18.425J)
Prereq.: 6.046J or 6.851 or 18.421
G (Fall)
3-0-9 H-LEVEL Grad Credit

A rigorous introduction to modern cryptography. Emphasis on the fundamental cryptographic primitives of public-key encryption, digital signatures, and pseudo-random number generation, and their computational complexity requirements.
*S. Goldwasser*

### 6.876J Advanced Topics in Cryptography

(Same subject as 18.426J)
Prereq.: 6.875J
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Recent results in cryptography and fault-tolerant distributed computing presented and discussed. Lectures by instructor, invited speakers, and students. Alternate years.
*S. Goldwasser*

### 6.891–6.899 Special Topics in the Computer Sciences

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

A seminar-type discussion of special topics in the computer sciences. Opportunity for graduate students and instructors to investigate a topic of common interest. Topic and staff announced each term. These subjects given independently or sequentially, as circumstances require.
*J. V. Guttag*

## Special Subjects

### 6.901 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 999.
*R. H. Rines*

### 6.910 Special Studies in Electrical Engineering and Computer Science

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

Opportunity for individual study at the undergraduate level related to electrical engineering and computer science not covered by other subjects offered by the Department. Student is responsible for initiation of arrangements and filing of proposal. Consult Department Undergraduate Office.
*A. C. Smith*

### 6.911–6.914 Special Advanced Undergraduate Subjects in Electrical Engineering and Computer Science

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

### 6.915–6.919 Special Advanced Undergraduate Subjects in Electrical Engineering and Computer Science

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

Advanced undergraduate subjects not offered in the regular curriculum. Consult Department to learn of offerings for a particular term. Registration by permission of instructor.
*A. C. Smith*

### 6.921 VI-A Internship

Prereq.: —
U (Summer)
0-12-0 [P/D/F]
Can be repeated for credit

Provides academic credit for the first two Assignments of VI-A students at companies affiliated with the Department's VI-A Internship Program. Students register for this subject twice. The grade of "J" is given following completion of the first Assignment. Students must complete the second Assignment in order to receive the full academic credit of 24 units for this subject. Enrollment limited to students participating in the VI-A Internship Program.
*M. Zahn*

### 6.922 Advanced VI-A Internship

Prereq.: 6.921
U (Spring, Summer)
0-12-0 [P/D/F]

Provides academic credit for the third Assignment of VI-A students at companies affiliated with the Department's VI-A Internship Program. Enrollment limited to students participating in the VI-A Internship Program.
*M. Zahn*

### 6.929 Undergraduate Project Presentation

Prereq.: —
U (Fall, Spring, Summer)
0-3-0
Can be repeated for credit

Registration for written presentation of the advanced undergraduate project, when the project work is carried out as part of a VI-A Assignment. Consult Department Undergraduate Office.
*A. C. Smith*

### 6.930 Management in Engineering

Prereq.: —
U (Fall)
3-0-9

Engineering School-Wide Elective Subject. Description given at end of this chapter in SWE section on page 562.
*J.-H. Chun, H. S. Marcus*

### 6.931 Development of Inventions and Creative Ideas

Prereq.: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Role of the engineer as patent expert and as technical witness in court and patent interference and related proceedings. Rights and obligations of engineers in connection with educational institutions, government, and large and small businesses. Various manners of transplanting inventions into business operations, including development of New England and other US electronics and biotech industries and their different types of institutions. American systems of incentive to creativity apart from the patent laws in the atomic energy and space fields. For graduate students only; others see 6.901.
*R. H. Rines*

### 6.936 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*

### 6.938 Engineering Risk-Benefit Analysis

Prereq.: 18.02
Acad Year 1996-97: G (Spring)
Acad Year 1997-98: **Not offered**
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.
*A. W. Drake, A. R. Odoni, G. Apostolakis*

### 6.946J Variational Mechanics: A Computational Approach

(Same subject as 12.620J, 8.351J)
Prereq.: 8.01, 18.03, 6.001 or equivalent
G (Fall)
3-3-6 H-LEVEL Grad Credit

See description under subject 12.620J.
*G. J. Sussman, J. Wisdom*

### 6.951 Graduate VI-A Internship

Prereq.: 6.922
G (Fall, Summer)
0-12-0 [P/D/F]

Provides academic credit for a Graduate Assignment of graduate students at companies affiliated with the Department's VI-A Internship Program. Enrollment limited to graduate students participating in the VI-A Internship Program.
*M. Zahn*

### 6.952 Graduate VI-A Internship

Prereq.: 6.951
G (Fall, Spring, Summer)
0-12-0 [P/D/F]

Provides academic credit for graduate students who require an additional term at the company to complete the Graduate Assignment of the Department's VI-A Internship Program. This academic credit is for registration purposes only and cannot be used toward fulfilling the requirements of any degree program. Enrollment limited to graduate students participating in the VI-A Internship Program.
*M. Zahn*

### 6.961 Introduction to Research in Electrical Engineering and Computer Science

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

Opportunity to become involved in graduate research, under guidance of a staff member, on a problem of mutual interest to student and supervisor. Recommended for all entering full-time graduate students in the Department of Electrical Engineering and Computer Science. Individual programs subject to approval of professor in charge. Enrollment restricted to regular graduate students in Electrical Engineering and Computer Science. Normal registration is for 12 units.
*F. R. Morgenthaler*

### 6.962–6.969 Special Studies in Electrical Engineering and Computer Science

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

Opportunity for study of graduate-level topics related to electrical engineering and computer science but not included elsewhere in the curriculum. Registration under this subject normally used for situations involving individual study (under supervision of a faculty member) of topics of mutual interest to student and supervisor, but may, when appropriate, be used for small study groups. Normal registration is for 12 units. Registration subject to approval of professor in charge.
*F. R. Morgenthaler*

### 6.971–6.979 Special Subjects in Electrical Engineering and Computer Science

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

Opportunity for group study of advanced subjects related to electrical engineering and computer science not otherwise included in curriculum. Offerings are initiated by members of EECS faculty on an ad hoc basis, subject to Departmental approval.
*F. R. Morgenthaler*

### 6.980 Teaching Electrical Engineering and Computer Science

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

For qualified students interested in gaining teaching experience. Classroom, tutorial, or laboratory teaching under the supervision of a faculty member. Enrollment limited by availability of suitable teaching assignments.
*F. C. Hennie*

### 6.981–6.989 Teaching Electrical Engineering and Computer Science

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

For Teaching Assistants in Electrical Engineering and Computer Science, in cases where teaching assignment is approved for academic credit by the Department.
*F. C. Hennie*

### 6.991–6.999 Research in Electrical Engineering and Computer Science

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

For Research Assistants in Electrical Engineering and Computer Science, in cases where the assigned research is approved for academic credit by the Department. Hours arranged with research supervisor.
*F. R. Morgenthaler*

### 6.UR Undergraduate Research in Electrical Engineering and Computer Science

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

Extended participation in the work of a faculty member or research group, including independent study of the literature, direct involvement in the group's research, and project work under an individual faculty member. Research is arranged by mutual agreement between the student and a member of the faculty of the Department of Electrical Engineering and Computer Science, and may continue over several terms. Forms and instructions for the initial letter of intent and final summary report are available in the Department Undergraduate Office. Grading P/D/F only.
*R. D. Thornton*

### 6.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 M.Eng., S.M., E.E., E.C.S., Ph.D., or Sc.D. thesis; to be arranged by the student and an appropriate MIT faculty member.
*F. R. Morgenthaler*