MECHANICAL ENGINEERING (COURSE 2)

First-Year Introductory Subjects

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

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

2.00B Toy Product Design
Prereq: None
U (Spring)
3-5-1 units

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

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

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

Core Undergraduate Subjects

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

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

2.000 Explorations in Mechanical Engineering
Prereq: None
U (Spring)
2-0-0 units

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Dynamics and Acoustics

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

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

2.033[J] Nonlinear Dynamics and Turbulence
Same subject as 1.686[J], 18.358[J]
Subject meets with 1.068
Prereq: 1.060A
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
3-2-7 units

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

2.034[J] Nonlinear Dynamics and Waves
Same subject as 1.685[J], 18.377[J]
Prereq: Permission of instructor
Acad Year 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
3-0-9 units

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

2.036[J] Nonlinear Dynamics and Chaos
Same subject as 18.385[J]
Prereq: 18.03 or 18.032
Acad Year 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
3-0-9 units

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

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

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

2.060[J] Structural Dynamics
Same subject as 1.581[J], 16.221[J]
Subject meets with 1.058
Prereq: 18.03 or permission of instructor
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Fall)
3-1-8 units

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

2.062[J] Wave Propagation
Same subject as 1.138[J], 18.376[J]
Prereq: 2.003[J] and 18.075
G (Spring)
3-0-9 units

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

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

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

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

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

Solid Mechanics and Materials

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

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

2.072 Mechanics of Continuous Media
Prereq: 2.071
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Fall)
3-0-9 units

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

2.073 Solid Mechanics: Plasticity and Inelastic Deformation
Prereq: 2.071
G (Fall)
Not offered regularly; consult department
3-0-9 units

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

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

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

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

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

2.076[J] Mechanics of Heterogeneous Materials
Same subject as 16.223[J]
Prereq: 2.002, 3.032, 16.20, or permission of instructor
Acad Year 2023-2024: G (Fall)
Acad Year 2024-2025: Not offered
3-0-9 units

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

2.077 Solid Mechanics: Coupled Theories (New)
Prereq: 2.072
G (Fall)
3-0-9 units

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

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

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

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

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

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

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

Computational Engineering

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

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

2.095 Introduction to Finite Element Methods
Subject meets with 2.098
Prereq: 2.086 or permission of instructor
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: U (Spring)
3-0-9 units

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

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

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

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

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

2.098 Introduction to Finite Element Methods
Subject meets with 2.095
Prereq: 2.086 or permission of instructor
G (Spring)
3-0-9 units

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

2.099[J] Computational Mechanics of Materials
Same subject as 16.225[J]
Prereq: Permission of instructor
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
3-0-9 units

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

System Dynamics and Control

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.153 Adaptive Control and Connections to Machine Learning
Prereq: 2.151
Acad Year 2023-2024: G (Fall)
Acad Year 2024-2025: Not offered
3-0-9 units

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

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

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

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

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

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

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

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

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

2.160 Identification, Estimation, and Learning
Prereq: 2.151
G (Fall)
3-0-9 units

Provides a broad theoretical basis for system identification, estimation, and learning. Least squares estimation and its convergence properties, Kalman filter and extended Kalman filter, noise dynamics and system representation, function approximation theory, neural nets, radial basis functions, wavelets, Volterra expansions, informative data sets, persistent excitation, asymptotic variance, central limit theorems, model structure selection, system order estimate, maximum likelihood, unbiased estimates, Cramer-Rao lower bound, Kullback-Leibler information distance, Akaike's information criterion, experiment design, and model validation.
H. Asada

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

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

2.166 Autonomous Vehicles
Prereq: 6.041B or permission of instructor
G (Spring)
Not offered regularly; consult department
3-1-8 units

Theory and application of probabilistic techniques for autonomous mobile robotics. Topics include probabilistic state estimation and decision making for mobile robots; stochastic representations of the environment; dynamic models and sensor models for mobile robots; algorithms for mapping and localization; planning and control in the presence of uncertainty; cooperative operation of multiple mobile robots; mobile sensor networks; application to autonomous marine (underwater and floating), ground, and air vehicles. Enrollment limited to 8.
J. J. Leonard

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

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

2.171 Analysis and Design of Digital Control Systems
Prereq: 2.14, 2.151, or permission of instructor
G (Fall)
Not offered regularly; consult department
3-3-6 units

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

2.174[J] Advancing Mechanics and Materials via Machine Learning
Same subject as 1.121[J]
Subject meets with 1.052
Prereq: Permission of instructor
G (Spring)
3-0-9 units

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

2.177[J] Designing Virtual Worlds (New)
Same subject as CMS.342[J]
Subject meets with 2.178[J], CMS.942[J]
Prereq: None
U (Fall, Spring)
3-1-2 units

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

2.178[J] Designing Virtual Worlds (New)
Same subject as CMS.942[J]
Subject meets with 2.177[J], CMS.342[J]
Prereq: None
G (Fall, Spring)
3-1-2 units

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

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

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

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

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

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

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

2.184 Biomechanics and Neural Control of Movement
Subject meets with 2.183[J], 9.34[J]
Prereq: 2.004 or permission of instructor
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: U (Spring)
3-0-9 units

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

Fluid Mechanics and Combustion

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

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

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

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

2.23 Hydrofoils and Propellers
Prereq: 2.20 and 18.085
Acad Year 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
3-0-9 units

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

2.24[J] Seakeeping of Ships and Offshore Energy Systems
Same subject as 1.692[J]
Prereq: 2.20 and 18.085
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
4-0-8 units

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

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

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

2.250[J] Fluids and Diseases
Same subject as 1.631[J], HST.537[J]
Subject meets with 1.063
Prereq: None
Acad Year 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
3-3-6 units

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

2.26[J] Advanced Fluid Dynamics
Same subject as 1.63[J]
Prereq: 18.085 and (2.25 or permission of instructor)
G (Spring)
4-0-8 units

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

2.28 Fundamentals and Applications of Combustion
Prereq: 2.006 or (2.051 and 2.06)
Acad Year 2023-2024: G (Fall)
Acad Year 2024-2025: Not offered
3-0-9 units

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

2.29 Numerical Fluid Mechanics
Subject meets with 2.290
Prereq: 18.075 and (2.006, 2.016, 2.06, 2.20, or 2.25)
G (Spring)
4-0-8 units

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

2.290 Numerical Fluid Mechanics
Subject meets with 2.29
Prereq: 2.005
U (Spring)
4-0-8 units

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

2.341[J] Macromolecular Hydrodynamics
Same subject as 10.531[J]
Prereq: 2.25, 10.301, or permission of instructor
G (Spring)
3-0-6 units

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

MEMS and Nanotechnology

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

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

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

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

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

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

Thermodynamics

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

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

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

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

Heat and Mass Transfer

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

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

2.51 Intermediate Heat and Mass Transfer
Prereq: (2.005 and 18.03) or permission of instructor
U (Fall)
3-0-9 units

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

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

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

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

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

2.57 Nano-to-Macro Transport Processes
Subject meets with 2.570
Prereq: 2.005, 2.051, or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

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

2.570 Nano-to-Macro Transport Processes
Subject meets with 2.57
Prereq: 2.005, 2.051, or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-9 units

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

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

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

2.59[J] Thermal Hydraulics in Power Technology
Same subject as 10.536[J], 22.313[J]
Prereq: 2.006, 10.302, 22.312, or permission of instructor
Acad Year 2023-2024: G (Fall)
Acad Year 2024-2025: Not offered
3-2-7 units

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

Energy and Power Systems

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.630 Interfacial Engineering (New)
Prereq: None
G (Fall)
3-0-9 units

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

2.65[J] Sustainable Energy
Same subject as 1.818[J], 10.391[J], 11.371[J], 22.811[J]
Subject meets with 2.650[J], 10.291[J], 22.081[J]
Prereq: Permission of instructor
G (Fall)
3-1-8 units

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

2.650[J] Introduction to Sustainable Energy
Same subject as 10.291[J], 22.081[J]
Subject meets with 1.818[J], 2.65[J], 10.391[J], 11.371[J], 22.811[J]
Prereq: Permission of instructor
U (Fall)
3-1-8 units

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

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

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

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

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

Experimental Engineering

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Oceanographic Engineering and Acoustics

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

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

2.681 Environmental Ocean Acoustics
Prereq: 2.066, 18.075, or permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

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

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

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

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

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

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

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

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

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

2.688 Principles of Oceanographic Instrument Systems -- Sensors and Measurements
Prereq: 2.671 and 18.075
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Fall)
3-3-6 units

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

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

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

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

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

Naval Architecture

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Optics

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

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

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

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

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

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

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

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

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

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

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

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

Design

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

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

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

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

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

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

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

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

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

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

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

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

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

See description under subject 6.910A.
B. Kotelly

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

See description under subject 6.910B.
B. Kotelly

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

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

2.733 Engineering Systems Design
Subject meets with 2.013
Prereq: (2.001, 2.003[J], (2.005 or 2.051), and (2.00B, 2.670, or 2.678)) or permission of instructor
Acad Year 2023-2024: G (Fall)
Acad Year 2024-2025: Not offered
0-6-6 units

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

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

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

2.737 Mechatronics
Prereq: 6.2000 and (2.14, 6.3100, or 16.30)
Acad Year 2023-2024: G (Fall)
Acad Year 2024-2025: Not offered
3-5-4 units

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.76 Global Engineering
Subject meets with 2.760
Prereq: 2.008 or permission of instructor
G (Fall)
3-0-9 units

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

2.760 Global Engineering
Subject meets with 2.76
Prereq: 2.008 or permission of instructor
U (Fall)
3-0-9 units

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

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

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

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

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

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

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

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

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

Bioengineering

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

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

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

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

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

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

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

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

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

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

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

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

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

See description under subject EC.797[J].
M. Yang, H. Quintus-Bosz, S. Grama, K. Bergeron

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Manufacturing

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

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

2.812 Solving for Carbon Neutrality at MIT
Prereq: None
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: U (Spring)
3-3-6 units

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

2.813 Energy, Materials, and Manufacturing
Subject meets with 2.83
Prereq: 2.008 or permission of instructor
Acad Year 2023-2024: U (Spring)
Acad Year 2024-2025: Not offered
3-0-9 units

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

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

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

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

See description under subject 3.371[J].
D. Baskin, A. Slocum

2.83 Energy, Materials and Manufacturing
Subject meets with 2.813
Prereq: 2.008 or permission of instructor
Acad Year 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
3-0-9 units

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

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

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

2.832 Solving for Carbon Neutrality at MIT
Prereq: None
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
3-3-6 units

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

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

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

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

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

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

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

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

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

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

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

2.874[J] Process Data Analytics
Same subject as 10.354[J]
Subject meets with 2.884[J], 10.554[J]
Prereq: 18.03 or permission of instructor
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: U (Fall)
4-0-8 units

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

2.884[J] Process Data Analytics
Same subject as 10.554[J]
Subject meets with 2.874[J], 10.354[J]
Prereq: None
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Fall)
4-0-8 units

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

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

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

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

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

Engineering Management

2.351[J] Introduction to Making and Hardware Ventures
Same subject as 15.351[J]
Prereq: Permission of instructor
G (Spring)
3-0-3 units

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

2.900 Ethics for Engineers
Engineering School-Wide Elective Subject.
Offered under: 1.082, 2.900, 6.9320, 10.01, 16.676, 22.014
Subject meets with 6.9321, 20.005
Prereq: None
U (Fall, Spring)
2-0-4 units

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

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

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

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

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

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

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

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

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

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

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

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

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

Advanced Topics and Special Subjects

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

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

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

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

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

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

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

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

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

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

2.989 Experiential Learning in Mechanical Engineering
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.S977 Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

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

2.S979 Graduate Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
Units arranged

Lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter.
L. Perez-Breva, D. Hart

2.S980 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Fall)
Units arranged [P/D/F]
Can be repeated for credit.

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

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

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

2.S982 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Spring)
Units arranged
Can be repeated for credit.

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

2.S983 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

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

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

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

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

2.S986 Special Subject in Mechanical Engineering
Prereq: None
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
Units arranged

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

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

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

2.S988 Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

2.S989 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
Units arranged [P/D/F]
Can be repeated for credit.

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

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

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

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

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

2.S992 Graduate Special Subject in Mechanical Engineering
Prereq: None
G (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

2.S993 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: U (Spring)
Units arranged
Can be repeated for credit.

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

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

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

2.S995 Undergraduate Special Subject in Mechanical Engineering
Prereq: None
U (Fall)
0-6-0 units
Can be repeated for credit.

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

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

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

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

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

2.S998 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Fall)
Units arranged
Can be repeated for credit.

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

2.S999 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

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

Thesis, Research and Practice

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

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

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

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

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

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

2.C01 Physical Systems Modeling and Design Using Machine Learning
Subject meets with 2.C51
Prereq: 2.086; *Coreq: 6.C01*
U (Spring; second half of term)
1-3-2 units
Credit cannot also be received for 1.C01, 1.C51, 2.C51, 3.C01[J], 3.C51[J], 10.C01[J], 10.C51[J], 20.C01[J], 20.C51[J], 22.C01, 22.C51, SCM.C51

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

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

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

2.C51 Physical Systems Modeling and Design Using Machine Learning
Subject meets with 2.C01
Prereq: 18.0751 or 18.0851; *Coreq: 6.C51*
G (Spring; second half of term)
1-3-2 units
Credit cannot also be received for 1.C01, 1.C51, 2.C01, 3.C01[J], 3.C51[J], 10.C01[J], 10.C51[J], 20.C01[J], 20.C51[J], 22.C01, 22.C51, SCM.C51

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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