CHEMICAL ENGINEERING (COURSE 10)

10.00 Molecule Builders
Prereq: Chemistry (GIR) and Physics I (GIR)
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: U (Spring)
1-6-2 units

Project-based introduction to the applications of engineering design at the molecular level. Working in teams, students complete an open-ended design project that focuses on a topic such as reactor or biomolecular engineering, chemical process design, materials and polymers, or energy. Provides students practical exposure to the field of chemical engineering as well as potential opportunities to continue their project designs in national/international competitions. Limited to 36; preference to first year students.
B. D. Olsen

10.000 Engineering Molecular Marvels: Careers and ChemE at MIT (New)
Prereq: None
U (Spring)
2-0-0 units

Exposes students to the ways in which chemical technologies have profoundly altered the course of history. Discusses the next century's great challenges, such as curing cancer and supplying the planet's surging demand for clean water, food and energy, sustainably. Provides an overview of how ChemE students apply fundamental engineering principles and leverage technology, from molecules to systems, in the pursuit of practical solutions for these problems and more.
T. A. Kinney, B. S. Johnston

10.01 Ethics for Engineers
Engineering School-Wide Elective Subject.
Offered under: 1.082, 2.900, 6.904, 10.01, 16.676, 22.014
Subject meets with 6.9041, 20.005
Prereq: None
U (Fall, Spring)
2-0-4 units

Integrates classical readings that provide an overview of ethics with a survey of case studies that focus on ethical problems arising in the practice of engineering. Readings taken from a variety of sources, such as Aristotle, Machiavelli, Bacon, Hobbes, Locke, the Founding Fathers, and the Bible. Case studies include written analyses and films that address engineering disasters, biotechnology, court cases, ethical codes, and the ultimate scope and aims of engineering. Students taking independent inquiry version 6.9041 expand the scope of their term project. Students taking 20.005 focus their term project on a problem in biological engineering in which there are intertwined ethical and technical issues.
D. Doneson, B. L. Trout

10.02 Foundations of Entrepreneurship for Engineers
Prereq: None
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: U (Spring)
3-0-9 units

Studies economic and leadership foundations of entrepreneurship as they relate to engineering. Case studies illustrate major impacts of engineering on the world and examine the leaders responsible for such impacts. Authors include Franklin, Keynes, Leonardo, Lincoln, Locke, Machiavelli, Marx, Schmidt, Schumpeter, Smith, Thiel, and Tocqueville. Discusses topics such as the difference between an entrepreneur and a manager, the entrepreneur as founder, and characteristics of principled entrepreneurship.
D. Doneson, B. L. Trout

10.03[J] Advances in Biomanufacturing
Same subject as 7.458[J]
Subject meets with 7.548[J], 10.53[J]
Prereq: None
U (Spring; second half of term)
1-0-2 units

Seminar examines how biopharmaceuticals, an increasingly important class of pharmaceuticals, are manufactured. Topics range from fundamental bioprocesses to new technologies to the economics of biomanufacturing. Also covers the impact of globalization on regulation and quality approaches as well as supply chain integrity. Students taking graduate version complete additional assignments.
J. C. Love, A. Sinskey, S. Springs

10.04 A Philosophical History of Energy
Prereq: None
U (Spring)
3-0-9 units

Philosophic and historical approach to conceptions of energy through the 19th century. Relation of long standing scientific and philosophic problems in the field of energy to 21st-century debates. Topics include the development of thermodynamics and kinetic theories, the foundation of the scientific project, the classical view of energy, and the harnessing of nature. Authors include Bacon, Boltzmann, Carnot, Compte, Descartes, Gibbs, Plato, Aristotle, Leibniz, Kant, Hegel, Mill, Peirce, Whitehead, and Maxwell. Key texts and controversies form topics of weekly writing assignments and term papers.
B. L. Trout, A. Schulman

10.05 Foundational Analyses of Problems in Energy and the Environment
Prereq: None
U (Spring)
3-0-9 units

Investigates key texts and papers on the foundational thought of current issues in energy and environmental science. Builds an understanding of key debates (scientific, ethical, and political). Aims to inform solutions to key problems related to procurement of energy and environmental degradation. Topics address alternative energy technologies and fossil fuel utilization and emissions, especially carbon dioxide, carbon dioxide sequestration, and geoengineering. Foundational readings from Homer and Greek playwrights, Aristotle, Genesis, Bacon, Locke, Rousseau, Coleridge, Carnot, Clausius, Marx, Heidegger, Carson, Gore, Singer, and Brundtland. Assignments include weekly analyses of readings, videos and related engineering calculations in addition to a final project. Limited to 18.
B. L. Trout

10.06 Advanced Topics in Ethics for Engineers
Prereq: 10.01, 10.05, and permission of instructor
U (Fall, Spring)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

In-depth study of varying advanced topics in ethics for engineers. Focuses on foundational works and their significance for the choices that engineers make, both as students and as practicing engineers. Each semester, different works and topics, based on current and perennial issues in ethics and engineering, will be chosen in order to explore facets of the extremely complex and varied subject of the place of engineering for the individual and society. Examples of topics include genetic engineering and what it means to be human, artificial intelligence and thought, the scope and limits of engineering, and engineering and freedom. May be repeated for credit with permission of instructor. Limited to 20.
B. L. Trout, D. Doneson

10.07 Debating About Society and Engineering (New)
Prereq: None
U (Fall, Spring)
3-0-6 units

Explores the various interconnections between society and engineering as expressed in a variety of media: speech, visualization, art and music, and writing. Analysis of foundational texts and art together with case studies form the basis for students' weekly assignments. Topics include the connection between engineering and society, the significance of artificial intelligence, evolution, social bias, and relativism of thought and culture. Includes oral and written presentations. Limited to 18.
E. Schiappa, B. L. Trout

10.08 Cultural Studies for Chemical Engineering Graduate Students (New)
Prereq: None
G (Fall)
2-0-4 units

Seminar explores some of the key cultural developments of human beings and their related engineering aspects together with insights into the evolution of chemical engineering. Begins with discussion of Warren K. Lewis on culture and civilization, in addition to other chemical engineering luminaries, Rutherford Aris and John Prausnitz, and Sam Florman. Following their leads, seminar addresses key developments in Greek culture, followed by Renaissance culture, and culminating with contemporary culture. Discusses the influence of chemical engineering throughout the term, but focuses on broader cultural understanding as advocated by Lewis and Aris. Weekly meetings and study question responses are complemented with direct experience of culture and its connection to engineering. Includes guests with various expertise in culture and chemical engineering.
B. L. Trout

10.10 Introduction to Chemical Engineering
Prereq: Calculus I (GIR), Chemistry (GIR), and Physics I (GIR)
U (Fall, Spring)
4-0-8 units

Explores the diverse applications of chemical engineering through example problems designed to build computer skills and familiarity with the elements of engineering design. Solutions require application of fundamental concepts of mass and energy conservation to batch and continuous systems involving chemical and biological processes. Problem-solving exercises distributed among lectures and recitation.
B. S. Johnston, K. L. J. Prather

10.213 Chemical and Biological Engineering Thermodynamics
Prereq: 5.60 and 10.10
U (Spring)
4-0-8 units

Thermodynamics of multicomponent, multiphase chemical and biological systems. Applications of first, second, and third laws of thermodynamics to open and closed systems. Properties of mixtures, including colligative properties, chemical reaction equilibrium, and phase equilibrium; non-ideal solutions; power cycles; refrigeration; separation systems.
K. K. Gleason, H. D. Sikes

10.22 Molecular Engineering
Prereq: 5.60 and 10.213
U (Spring)
3-0-9 units

Introduces molecular concepts in relation to engineering thermodynamics. Includes topics in statistical mechanics, molecular description of gases and liquids, property estimation, description of equilibrium and dynamic properties of fluids from molecular principles, and kinetics of activated processes. Also covers some basic aspects of molecular simulation and applications in systems of engineering interest.
G. C. Rutledge, P. S. Doyle

10.25 Industrial Chemistry and Chemical Process Pathways
Prereq: Chemistry (GIR), 10.213, and 10.37
G (Fall)
Not offered regularly; consult department
3-0-6 units

Chemical and engineering principles involved in creation and operation of viable industrial processes. Topics: analysis of process chemistry by p-pathways (i.e., radical, ionic, and pericyclic reactions of organic syntheses) and d-pathways (i.e., catalysis by transition-metal complexes). Use of reaction mechanisms for inference of co-product formation, kinetics, and equilibria: process synthesis logic related to reaction selectivity, recycle, separations. Illustrations drawn from current and contemplated commercial practice.
P. S. Virk

10.26 Chemical Engineering Projects Laboratory
Subject meets with 10.27, 10.29
Prereq: (10.302 and (2.671, 3.014, 5.310, 7.02[J], 12.335, 20.109, (1.106 and 1.107), or (5.351, 5.352, and 5.353))) or permission of instructor
U (Spring)
3-8-4 units

Projects in applied chemical engineering research. Students work in teams on one project for the term. Projects often suggested by local industry. Includes training in project planning and project management, execution of experimental work, data analysis, oral presentation, individual and collaborative report writing.
C. K. Colton, B. S. Johnston, B. D. Burrell, G. C. Rutledge

10.27 Energy Engineering Projects Laboratory
Subject meets with 10.26, 10.29
Prereq: (10.302 and (2.671, 3.014, 5.310, 7.02[J], 12.335, 20.109, (1.106 and 1.107), or (5.351, 5.352, and 5.353))) or permission of instructor
U (Spring)
3-8-4 units

Projects in applied energy engineering research. Students work in teams on one project for the term. Projects often suggested by local industry. Includes training in project planning and project management, execution of experimental work, data analysis, oral presentation, individual and collaborative report writing. Preference to Energy Studies minors.
G. C. Rutledge

10.28 Chemical-Biological Engineering Laboratory
Prereq: ((5.07[J] or 7.05) and (5.310 or 7.02[J])) or permission of instructor
U (Fall)
2-8-5 units
Credit cannot also be received for 10.28B

Introduces the complete design of the bioprocess: from vector selection to production, separation, and characterization of recombinant products. Utilize concepts from many fields, such as, chemical and electrical engineering, and biology. Student teams work through parallel modules spanning microbial fermentation and animal cell culture. With the bioreactor at the core of the experiments, students study cell metabolism and biological pathways, kinetics of cell growth and product formation, oxygen mass transport, scale-up and techniques for the design of process control loops. Introduces novel bioreactors and powerful analytical instrumentation. Downstream processing and recombinant product purification also included. Credit cannot also be received for 10.28A. Enrollment limited.
J.-F. Hamel

10.28A Chemical-Biological Engineering Laboratory I: Introduction to Lab Experiments (10.28L)
Prereq: ((5.07[J] or 7.05) and (5.310 or 7.02[J])) or permission of instructor
U (IAP, Spring)
1-3-0 units

First in a two-subject sequence that spans IAP and spring term, and covers the same content as 10.28; see 10.28 for description. Course utilizes online learning technologies and simulations in addition to traditional lab experiments. 10.28A comprises the major lab portion of the subject. Credit cannot also be received for 10.28. Enrollment limited.
J.-F. Hamel

10.28B Chemical-Biological Engineering Laboratory II: Long-term, Online and Simulated Experiments (New)
Prereq: 10.28A
U (Spring)
1-2-8 units
Credit cannot also be received for 10.28

Second in a two-subject sequence that spans IAP and spring term, and covers the same content as 10.28; see 10.28 for description. Course utilizes online learning technologies and simulations in addition to traditional lab experiments. 10.28B comprises the simulation portion of the subject, and most of the communication component. Enrollment limited.
J.-F. Hamel

10.29 Biological Engineering Projects Laboratory
Subject meets with 10.26, 10.27
Prereq: (10.302 and (2.671, 3.014, 5.310, 7.02[J], 12.335, 20.109, (1.106 and 1.107), or (5.351, 5.352, and 5.353))) or permission of instructor
U (Spring)
3-8-4 units

Projects in applied biological engineering research. Students work in teams on one project for the term. Projects often suggested by local industry. Includes training in project planning and project management, execution of experimental work, data analysis, oral presentation, individual and collaborative report writing.
G. C. Rutledge

10.291[J] Introduction to Sustainable Energy
Same subject as 2.650[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

10.301 Fluid Mechanics
Prereq: 10.10 and 18.03
U (Spring)
4-0-8 units. REST

Introduces the mechanical principles governing fluid flow. Stress in a fluid. Conservation of mass and momentum, using differential and integral balances. Elementary constitutive equations. Hydrostatics. Exact solutions of the Navier-Stokes equations. Approximate solutions using control volume analysis. Mechanical energy balances and Bernoulli's equation. Dimensional analysis and dynamic similarity. Introduces boundary-layer theory and turbulence.
P. S. Doyle, F. R. Brushett

10.302 Transport Processes
Prereq: (5.60, 10.213, and 10.301) or permission of instructor
U (Fall)
4-0-8 units

Principles of heat and mass transfer. Steady and transient conduction and diffusion. Radiative heat transfer. Convective transport of heat and mass in both laminar and turbulent flows. Emphasis on the development of a physical understanding of the underlying phenomena and upon the ability to solve real heat and mass transfer problems of engineering significance.
K. Manthiram, K. Chung

10.31 Nanoscale Energy Transport Processes
Subject meets with 10.51
Prereq: ((2.51 or 10.302) and (3.024 or 5.61)) or permission of instructor
U (Fall)
Not offered regularly; consult department
3-0-9 units

Explores the impact of nanoscale phenomena on macroscale transport of energy-carrying molecules, phonons, electrons, and excitons. Studies the effect of structural and energetic disorder, wave-like vs. particle-like transport, quantum and classical size effects, and quantum coherence. Emphasizes quantitative analysis, including the Boltzmann transport equation, Einstein relation, Wiedemann-Franz law, and Marcus electron transfer theory. Also addresses percolation theory and the connection to energy conversion technologies, such as solar cells, thermoelectrics, and LEDs. Students taking graduate version complete additional assignments.
W. A. Tisdale

10.32 Separation Processes
Prereq: 10.213 and 10.302
U (Spring)
2-0-4 units

General principles of separation by equilibrium and rate processes. Staged cascades. Applications to distillation, absorption, adsorption, and membrane processes. Use of material balances, phase equilibria, and diffusion to understand and design separation processes.
T. A. Hatton

10.333 Introduction to Modeling and Simulation
Engineering School-Wide Elective Subject.
Offered under: 1.021, 3.021, 10.333, 22.00
Prereq: 3.016, 18.03, or permission of instructor
U (Spring)
4-0-8 units. REST

See description under subject 3.021.
M. Buehler, R. Gomez-Bombarelli

10.34 Numerical Methods Applied to Chemical Engineering
Prereq: Permission of instructor
G (Fall)
3-0-6 units

Numerical methods for solving problems arising in heat and mass transfer, fluid mechanics, chemical reaction engineering, and molecular simulation. Topics: numerical linear algebra, solution of nonlinear algebraic equations and ordinary differential equations, solution of partial differential equations (e.g., Navier-Stokes), numerical methods in molecular simulation (dynamics, geometry optimization). All methods are presented within the context of chemical engineering problems. Familiarity with structured programming is assumed.
W. H. Green, J. W. Swan

10.345 Fundamentals of Metabolic and Biochemical Engineering: Applications to Biomanufacturing
Subject meets with 10.545
Prereq: 5.07[J], 7.05, or permission of instructor
U (Spring)
3-0-9 units

Examines the fundamentals of cell and metabolic engineering for biocatalyst design and optimization, as well as biochemical engineering principles for bioreactor design and operation, and downstream processing. Presents applications of microbial processes for production of commodity and specialty chemicals and biofuels in addition to mammalian cell cultures for production of biopharmaceuticals. Students taking graduate version complete additional assignments.
Gr. Stephanopoulos

10.37 Chemical Kinetics and Reactor Design
Prereq: 5.60 and 10.301
U (Spring)
3-0-6 units

Applies the concepts of reaction rate, stoichiometry and equilibrium to the analysis of chemical and biological reacting systems. Derivation of rate expressions from reaction mechanisms and equilibrium or steady state assumptions. Design of chemical and biochemical reactors via synthesis of chemical kinetics, transport phenomena, and mass and energy balances. Topics: chemical/biochemical pathways; enzymatic, pathway and cell growth kinetics; batch, plug flow and well-stirred reactors for chemical reactions and cultivations of microorganisms and mammalian cells; heterogeneous and enzymatic catalysis; heat and mass transport in reactors, including diffusion to and within catalyst particles and cells or immoblized enzymes.
Gr. Stephanopoulos, Y. Roman

10.390[J] Fundamentals of Advanced Energy Conversion
Same subject as 2.60[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
Acad Year 2018-2019: U (Spring)
Acad Year 2019-2020: Not offered
4-0-8 units

See description under subject 2.60[J].
A. F. Ghoniem, W. Green

10.391[J] Sustainable Energy
Same subject as 1.818[J], 2.65[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

10.392[J] Fundamentals of Advanced Energy Conversion
Same subject as 2.62[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

See description under subject 2.62[J].
A. F. Ghoniem, W. Green

10.40 Chemical Engineering Thermodynamics
Prereq: 10.213
G (Fall)
4-0-8 units

Basic postulates of classical thermodynamics. Application to transient open and closed systems. Criteria of stability and equilibria. Constitutive property models of pure materials and mixtures emphasizing molecular-level effects using the formalism of statistical mechanics. Phase and chemical equilibria of multicomponent systems. Applications emphasized through extensive problem work relating to practical cases.
D. Blankschtein

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

Introduction to the substance and process of funding technology startups. Topics include a comparative analysis of various sources of capital; templates to identify the optimal investor; legal frameworks, US and offshore, of the investment process and its related jargon; an introduction to understanding venture capital as a business; and market practice and standards for term sheet negotiation. Emphasizes strategy as well as tactics necessary to negotiate and build effective, long-term relationships with investors, particularly venture capital firms (VCs).
S. Loessberg, D. P. Hart

10.424 Pharmaceutical Engineering
Subject meets with 10.524
Prereq: 10.213
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: U (Fall)
3-0-6 units

Presents engineering principles and unit operations involved in the manufacture of small molecules pharmaceuticals, from the isolation of purified active pharmaceutical ingredients (API) to the final production of drug product. Regulatory issues include quality by design and process analytical technologies of unit operations, such as crystallization, filtration, drying, milling, blending, granulation, tableting and coating. Also covers principles of formulation for solid dosage forms and parenteral drugs. Students taking graduate version complete additional assignments. Limited to 50.
A. S. Myerson

10.426 Electrochemical Energy Systems
Subject meets with 10.626
Prereq: 10.302 or permission of instructor
U (Spring)
3-0-9 units

Introduces electrochemical energy systems from the perspective of thermodynamics, kinetics, and transport. Surveys analysis and design of electrochemical reactions and processes by integrating chemical engineering fundamentals with knowledge from diverse fields, including chemistry, electrical engineering, and materials science. Includes applications to fuel cells, electrolyzers, and batteries. Students taking graduate version complete additional assignments.
K. Manthiram

10.43 Introduction to Interfacial Phenomena
Prereq: 10.213 or introductory subject in thermodynamics or physical chemistry
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Spring)
3-0-6 units

Introduces fundamental and applied aspects of interfacial systems. Theory of capillarity. Experimental determination of surface and interfacial tensions. Thermodynamics of interfaces. The Gibbs adsorption equation. Charged interfaces. Surfactant adsorption at interfaces. Insoluble monolayers. Curvature effects on the equilibrium state of fluids. Nucleation and growth. Fundamentals of wetting and contact angle. Adhesion, cohesion, and spreading. Wetting of textured surfaces. Super-hydrophilic and super-hydrophobic surfaces. Self-cleaning surfaces.
D. Blankschtein

10.437[J] Computational Chemistry
Same subject as 5.697[J]
Subject meets with 5.698[J], 10.637[J]
Prereq: None
U (Fall)
3-0-9 units

Addresses both the theory and application of first-principles computer simulations methods (i.e., quantum, chemical, or electronic structure), including Hartree-Fock theory, density functional theory, and correlated wavefunction methods. Covers enhanced sampling, ab initio molecular dynamics, and transition-path-finding approaches as well as errors and accuracy in total and free energies. Discusses applications such as the study and prediction of properties of chemical systems, including heterogeneous, molecular, and biological catalysts (enzymes), and physical properties of materials. Students taking graduate version complete additional assignments.
H. J. Kulik

10.441[J] Molecular and Engineering Aspects of Biotechnology
Same subject as 7.37[J], 20.361[J]
Prereq: (7.06 and (2.005, 3.012, 5.60, or 20.110[J])) or permission of instructor
U (Spring)
Not offered regularly; consult department
4-0-8 units
Credit cannot also be received for 7.371

See description under subject 7.37[J].
H. Lodish, L. Griffith

10.443 Future Medicine: Drug Delivery, Therapeutics, and Diagnostics
Subject meets with 10.643[J], HST.526[J]
Prereq: 5.12 or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-6 units

Aims to describe the direction and future of medical technology. Introduces pharmaceutics, pharmacology, and conventional medical devices, then transitions to drug delivery systems, mechanical/electric-based and biological/cell-based therapies, and sensors. Covers nano- and micro drug delivery systems, including polymer-drug conjugates, protein therapeutics, liposomes and polymer nanoparticles, viral and non-viral genetic therapy, and tissue engineering. Previous coursework in cell biology and organic chemistry recommended. Students taking graduate version complete additional assignments. Limited to 40.
D. G. Anderson

10.450 Process Dynamics, Operations, and Control
Prereq: 10.302 and 18.03
U (Spring)
3-0-6 units

Introduction to dynamic processes and the engineering tasks of process operations and control. Subject covers modeling the static and dynamic behavior of processes; control strategies; design of feedback, feedforward, and other control structures; model-based control; applications to process equipment.
B. S. Johnston

10.466 Structure of Soft Matter
Subject meets with 10.566
Prereq: 5.60
Acad Year 2018-2019: U (Fall)
Acad Year 2019-2020: Not offered
3-0-6 units

Provides an introduction to the basic thermodynamic language used for describing the structure of materials, followed by a survey of the scattering, microscopy and spectroscopic techniques for structure and morphology characterization. Applies these concepts to a series of case studies illustrating the diverse structures formed in soft materials and the common length, time and energy scales that unify this field. For students interested in studying polymer science, colloid science, nanotechnology, biomaterials, and liquid crystals. Students taking graduate version complete additional assignments.
B. D. Olsen

10.467 Polymer Science Laboratory
Prereq: 5.12 and 5.310
U (Fall)
2-7-6 units

Experiments broadly aimed at acquainting students with the range of properties of polymers, methods of synthesis, and physical chemistry. Examples: solution polymerization of acrylamide, bead polymerization of divinylbenzene, interfacial polymerization of nylon 6,10. Evaluation of networks by tensile and swelling experiments. Rheology of polymer solutions and suspensions. Physical properties of natural and silicone rubber. Preference to Course 10 seniors and juniors.
J. C. Love, D. G. Anderson

10.489 Concepts in Modern Heterogeneous Catalysis
Subject meets with 10.689
Prereq: 10.302 and 10.37
U (Spring)
Not offered regularly; consult department
3-0-6 units

Explores topics in the design and implementation of heterogeneous catalysts for chemical transformations. Emphasizes use of catalysis for environmentally benign and sustainable chemical processes. Lectures address concepts in catalyst preparation, catalyst characterization, quantum chemical calculations, and microkinetic analysis of catalytic processes. Shows how experimental and theoretical approaches can illustrate important reactive intermediates and transition states involved in chemical reaction pathways, and uses that information to help identify possible new catalysts that may facilitate reactions of interest. Draws examples from current relevant topics in catalysis. Includes a group project in which students investigate a specific topic in greater depth. Students taking graduate version complete additional assignments.
Y. Roman

10.490 Integrated Chemical Engineering
Prereq: 10.37
U (Fall, Spring)
3-0-6 units
Can be repeated for credit.

Presents and solves chemical engineering problems in an industrial context. Emphasis on the integration of fundamental concepts with approaches in process design, and on problems that demand synthesis, economic analysis, and process design; consideration of safety analysis, process dynamics and the use of process simulators and related tools to approach such problems. The specific application of these fundamental concepts will vary each term, and may include chemical, electrochemical, pharmaceutical, biopharmaceutical (biologic) or related processes, operated in batch, semi-batch, continuous or hybrid mode. May be repeated once for credit with permission of instructor.
B. S. Johnston, Y. Roman

10.492A Integrated Chemical Engineering Topics I (10.492)
Prereq: 10.301 and permission of instructor
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: U (Fall; first half of term)
2-0-4 units
Credit cannot also be received for 10.492B

Chemical engineering problems presented and analyzed in an industrial context. Emphasizes the integration of fundamentals with material property estimation, process control, product development, and computer simulation. Integration of societal issues, such as engineering ethics, environmental and safety considerations, and impact of technology on society are addressed in the context of case studies. 10.37 and 10.302 required for certain topic modules. See departmental website for individual ICE-T module descriptions.
K. F. Jensen, Geo. Stephanopoulos

10.492B Integrated Chemical Engineering Topics I (New)
Prereq: 10.301 and permission of instructor
U (Fall; second half of term)
2-0-4 units
Credit cannot also be received for 10.492A

Chemical engineering problems presented and analyzed in an industrial context. Emphasizes the integration of fundamentals with material property estimation, process control, product development, and computer simulation. Integration of societal issues, such as engineering ethics, environmental and safety considerations, and impact of technology on society are addressed in the context of case studies. 10.37 and 10.302 required for certain topic modules. See departmental website for individual ICE-T module descriptions.
K. F. Jensen, Geo. Stephanopoulos

10.493 Integrated Chemical Engineering Topics II
Prereq: 10.301 and permission of instructor
U (IAP; partial term)
2-0-4 units

Chemical engineering problems presented and analyzed in an industrial context. Emphasizes the integration of fundamentals with material property estimation, process control, product development, and computer simulation. Integration of societal issues, such as engineering ethics, environmental and safety considerations, and impact of technology on society are addressed in the context of case studies. 10.37 and 10.302 required for certain topic modules. See departmental website for individual ICE-T module descriptions.
J. Drake

10.494A Integrated Chemical Engineering Topics III (10.494)
Prereq: 10.301 and permission of instructor
U (Spring)
2-0-4 units
Credit cannot also be received for 10.494B

Chemical engineering problems presented and analyzed in an industrial context. Emphasizes the integration of fundamentals with material property estimation, process control, product development, and computer simulation. Integration of societal issues, such as engineering ethics, environmental and safety considerations, and impact of technology on society are addressed in the context of case studies. 10.37 and 10.302 required for certain topic modules. See departmental website for individual ICE-T module descriptions.
K. F. Jensen, R. C. Armstrong

10.494B Integrated Chemical Engineering Topics III (New)
Prereq: 10.301 and permission of instructor
U (Spring; second half of term)
2-0-2 units
Credit cannot also be received for 10.494A

Chemical engineering problems presented and analyzed in an industrial context. Emphasizes the integration of fundamentals with material property estimation, process control, product development, and computer simulation. Integration of societal issues, such as engineering ethics, environmental and safety considerations, and impact of technology on society are addressed in the context of case studies. 10.37 and 10.302 required for certain topic modules. See departmental website for individual ICE-T module descriptions.
K. F. Jensen, R. C. Armstrong

10.495 Molecular Design and Bioprocess Development of Immunotherapies
Subject meets with 10.595
Prereq: 7.06 or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-6 units

Examines challenges and opportunities for applying chemical engineering principles to address the growing global burden of infectious disease, including drug-resistant strains and neglected pathogens. Topics include a historical overview of vaccines and immunotherapies, the molecular design considerations for new immunotherapies and adjuvants, the economic challenges for process development and manufacturing of immunotherapies, and new technologies for designing and assessing therapies. Case studies to cover topics for specific diseases. Students taking graduate version complete additional assignments.
J. C. Love

10.50 Analysis of Transport Phenomena
Prereq: 10.301 and 10.302
G (Fall)
4-0-8 units

Unified treatment of heat transfer, mass transfer, and fluid mechanics, emphasizing scaling concepts in formulating models and analytical methods for obtaining solutions. Topics include conduction and diffusion, laminar flow regimes, convective heat and mass transfer, and simultaneous heat and mass transfer with chemical reaction or phase change.
W. M. Deen, M. Z. Bazant

10.51 Nanoscale Energy Transport Processes
Subject meets with 10.31
Prereq: ((2.51 or 10.302) and (3.024 or 5.61)) or permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

Explores the impact of nanoscale phenomena on macroscale transport of energy-carrying molecules, phonons, electrons, and excitons. Studies the effect of structural and energetic disorder, wave-like vs. particle-like transport, quantum and classical size effects, and quantum coherence. Emphasizes quantitative analysis, including the Boltzmann transport equation, Einstein relation, Wiedemann-Franz law, and Marcus electron transfer theory. Also addresses percolation theory and the connection to energy conversion technologies, such as solar cells, thermoelectrics, and LEDs. Students taking graduate version complete additional assignments.
W. A. Tisdale

10.52 Mechanics of Fluids
Prereq: 10.50
G (Fall)
Not offered regularly; consult department
3-0-6 units

Advanced subject in fluid and continuum mechanics. Content includes kinematics, macroscopic balances for linear and angular momentum, the stress tensor, creeping flows and the lubrication approximation, the boundary layer approximation, linear stability theory, and some simple turbulent flows.
Staff

10.524 Pharmaceutical Engineering
Subject meets with 10.424
Prereq: None
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall)
3-0-6 units

Presents engineering principles and unit operations involved in the manufacture of small molecules pharmaceuticals, from the isolation of purified active pharmaceutical ingredients (API) to the final production of drug product. Regulatory issues include quality by design and process analytical technologies of unit operations, such as crystallization, filtration, drying, milling, blending, granulation, tableting and coating. Also covers principles of formulation for solid dosage forms and parenteral drugs. Students taking graduate version complete additional assignments. Limited to 50.
A. S. Myerson

10.53[J] Advances in Biomanufacturing
Same subject as 7.548[J]
Subject meets with 7.458[J], 10.03[J]
Prereq: None
G (Spring; second half of term)
1-0-2 units

Seminar examines how biopharmaceuticals, an increasingly important class of pharmaceuticals, are manufactured. Topics range from fundamental bioprocesses to new technologies to the economics of biomanufacturing. Also covers the impact of globalization on regulation and quality approaches as well as supply chain integrity. Students taking graduate version complete additional assignments.
J. C. Love, A. Sinskey, S. Springs

10.531[J] Macromolecular Hydrodynamics
Same subject as 2.341[J]
Prereq: 2.25, 10.301, or permission of instructor
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Spring)
3-0-6 units

See description under subject 2.341[J].
R. C. Armstrong, G. H. McKinley

10.536[J] Thermal Hydraulics in Power Technology
Same subject as 2.59[J], 22.313[J]
Prereq: 2.006, 10.302, 22.312, or permission of instructor
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall)
3-2-7 units

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

10.537[J] Molecular, Cellular, and Tissue Biomechanics
Same subject as 2.798[J], 3.971[J], 6.524[J], 20.410[J]
Prereq: Biology (GIR) and (2.002, 2.006, 6.013, 10.301, or 10.302)
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall)
3-0-9 units

See description under subject 20.410[J].
R. D. Kamm, K. J. Van Vliet

10.538[J] Principles of Molecular Bioengineering
Same subject as 20.420[J]
Prereq: 7.06 and 18.03
G (Fall)
3-0-9 units

See description under subject 20.420[J].
A. Jasanoff, E. Fraenkel

10.539[J] Fields, Forces, and Flows in Biological Systems
Same subject as 2.795[J], 6.561[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

10.540 Intracellular Dynamics
Prereq: 7.06, 10.302, 18.03, or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Covers current models and descriptions of the internal cell dynamics of macromolecules due to reaction and transport. Two major areas will be explored: the process of gene expression, including protein-DNA interactions, chromatin dynamics, and the stochastic nature of gene expression; and cell signaling systems, especially those that lead to or rely on intracellular protein gradients. This class is intended for graduate students or advanced undergraduates with some background in cell biology, transport, and kinetics. An introductory class in probability is recommended.
N. Maheshri

10.542 Biochemical Engineering
Prereq: Permission of instructor
Acad Year 2018-2019: G (Spring)
Acad Year 2019-2020: Not offered
3-0-6 units

Interaction of chemical engineering, biochemistry, and microbiology. Mathematical representations of microbial systems. Kinetics of growth, death, and metabolism. Continuous fermentation, agitation, mass transfer, and scale-up in fermentation systems, enzyme technology.
K. J. Prather

10.544 Metabolic and Cell Engineering
Prereq: 7.05, 10.302, and 18.03
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units

Presentation of a framework for quantitative understanding of cell functions as integrated molecular systems. Analysis of cell-level processes in terms of underlying molecular mechanisms based on thermodynamics, kinetics, mechanics, and transport principles, emphasizing an engineering, problem-oriented perspective. Objective is to rationalize target selection for genetic engineering and evaluate the physiology of recombinant cells. Topics include cell metabolism and energy production, transport across cell compartment barriers, protein synthesis and secretion, regulation of gene expression, transduction of signals from extracellular environment, cell proliferation, cell adhesion and migration.
Gr. Stephanopoulos

10.545 Fundamentals of Metabolic and Biochemical Engineering: Applications to Biomanufacturing
Subject meets with 10.345
Prereq: 5.07[J], 7.05, or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Examines the fundamentals of cell and metabolic engineering for biocatalyst design and optimization, as well as biochemical engineering principles for bioreactor design and operation, and downstream processing. Presents applications of microbial processes for production of commodity and specialty chemicals and biofuels in addition to mammalian cell cultures for production of biopharmaceuticals. Students taking graduate version complete additional assignments.
Gr. Stephanopoulos

10.546[J] Statistical Thermodynamics
Same subject as 5.70[J]
Prereq: 5.60 or permission of instructor
G (Fall)
3-0-9 units

See description under subject 5.70[J].
J. Cao, A. Willard

10.547[J] Principles and Practice of Drug Development
Same subject as 7.547[J], 15.136[J], HST.920[J], IDS.620[J]
Prereq: Permission of instructor
G (Fall)
3-0-6 units

See description under subject 15.136[J].
T. J. Allen, C. L. Cooney, S. N. Finkelstein, A. J. Sinskey, G. K. Raju

10.548[J] Tumor Microenvironment and Transport Phenomena: A Systems Biology Approach
Same subject as HST.525[J]
Prereq: 10.301 and 18.03
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall)
2-0-4 units

See description under subject HST.525[J].
R. K. Jain

10.55 Colloid and Surfactant Science
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-6 units

Introduces fundamental and applied aspects of colloidal dispersions, where the typical particle size is less than a micrometer. Discusses the characterization and unique behavior of colloidal dispersions, including their large surface-to-volume ratio, tendency to sediment in gravitational and centrifugal fields, diffusion characteristics, and ability to generate osmotic pressure and establish Donnan equilibrium. Covers the fundamentals of attractive van der Waals forces and repulsive electrostatic forces. Presents an in-depth discussion of electrostatic and polymer-induced colloid stabilization, including the DLVO theory of colloid stability. Presents an introductory discussion of surfactant physical chemistry.
D. Blankschtein

10.551 Systems Engineering
Prereq: 10.213, 10.302, and 10.37
G (Spring)
3-0-6 units

Introduction to the elements of systems engineering. Special attention devoted to those tools that help students structure and solve complex problems. Illustrative examples drawn from a broad variety of chemical engineering topics, including product development and design, process development and design, experimental and theoretical analysis of physico-chemical process, analysis of process operations.
R. D. Braatz, P. I. Barton

10.552 Modern Control Design
Prereq: None
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall)
3-0-6 units

Covers modern methods for dynamical systems analysis, state estimation, controller design, and related topics. Uses example applications to demonstrate Lyapunov and linear matrix inequality-based methods that explicitly address actuator constraints, nonlinearities, and model uncertainties. Limited to 30.
R. D. Braatz

10.553 Model Predictive Control (New)
Prereq: None
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall)
3-0-6 units

Provides an introduction to the multivariable control of dynamical systems with constraints on manipulated, state, and output variables. Covers multiple mathematical formulations that are popular in academia and industry, including dynamic matrix control and state-space model predictive control of uncertain, nonlinear, and large-scale systems. Uses numerous real industrial processes as examples.
R. D. Braatz

10.554 Process Data Analytics (New)
Prereq: None
G (Fall)
3-0-6 units

Provides an introduction to data analytics for manufacturing processes. Topics include chemometrics, discriminant analysis, hyperspectral imaging, machine learning, big data, Bayesian methods, experimental design, feature spaces, and pattern recognition as relevant to manufacturing process applications, such as state and output estimation, process control, and fault detection, identification, and diagnosis.
R. D. Braatz

10.555[J] Bioinformatics: Principles, Methods and Applications
Same subject as HST.940[J]
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Introduction to bioinformatics, the collection of principles and computational methods used to upgrade the information content of biological data generated by genome sequencing, proteomics, and cell-wide physiological measurements of gene expression and metabolic fluxes. Fundamentals from systems theory presented to define modeling philosophies and simulation methodologies for the integration of genomic and physiological data in the analysis of complex biological processes. Various computational methods address a broad spectrum of problems in functional genomics and cell physiology. Application of bioinformatics to metabolic engineering, drug design, and biotechnology also discussed.
Gr. Stephanopoulos, I. Rigoutsos

10.557 Mixed-integer and Nonconvex Optimization
Prereq: 10.34 or 15.053
G (Spring)
3-0-9 units

Presents the theory and practice of deterministic algorithms for locating the global solution of NP-hard optimization problems. Recurring themes and methods are convex relaxations, branch-and-bound, cutting planes, outer approximation and primal-relaxed dual approaches. Emphasis is placed on the connections between methods. These methods will be applied and illustrated in the development of algorithms for mixed-integer linear programs, mixed-integer convex programs, nonconvex programs, mixed-integer nonconvex programs, and programs with ordinary differential equations embedded. The broad range of engineering applications for these optimization formulations will also be emphasized. Students will be assessed on homework and a term project for which examples from own research are encouraged.
P. I. Barton

10.56 Advanced Topics in Surfactant Science
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-6 units

Introduces fundamental advances and practical aspects of surfactant self-assembly in aqueous media. In-depth discussion of surfactant micellization, including statistical-thermodynamics of micellar solutions, models of micellar growth, molecular models for the free energy of micellization, and geometric packing theories. Presents an introductory examination of mixed micelle and vesicle formation, polymer-surfactant complexation, biomolecule-surfactant interactions, and micellar-assisted solubilization. Discusses molecular dynamics simulations of self-assembling systems. Covers recent advances in surfactant-induced dispersion and stabilization of colloidal particles (e.g., carbon nanotubes and graphene) in aqueous media. Examines surfactant applications in consumer products, environmental and biological separations, enhanced oil recovery using surfactant flooding, mitigation of skin irritation induced by surfactant-containing cosmetic products, and enhanced transdermal drug delivery using ultrasound and surfactants.
D. Blankschtein

10.560 Structure and Properties of Polymers
Prereq: 10.213 or permission of instructor
G (Spring)
3-0-6 units

Review of polymer molecular structure and bulk morphology; survey of molecular and morphological influence on bulk physical properties including non-Newtonian flow, macromolecular diffusion, gas transport in polymers, electrical and optical properties, solid-state deformation, and toughness. Case studies for product design.
R. E. Cohen

10.562[J] Pioneering Technologies for Interrogating Complex Biological Systems
Same subject as HST.562[J]
Prereq: None
G (Spring)
3-1-8 units

See description under subject HST.562[J]. Limited to 15.
K. Chung

10.566 Structure of Soft Matter
Subject meets with 10.466
Prereq: 5.60
Acad Year 2018-2019: G (Fall)
Acad Year 2019-2020: Not offered
3-0-6 units

Provides an introduction to the basic thermodynamic language used for describing the structure of materials, followed by a survey of the scattering, microscopy and spectroscopic techniques for structure and morphology characterization. Applies these concepts to a series of case studies illustrating the diverse structures formed in soft materials and the common length, time and energy scales that unify this field. For students interested in studying polymer science, colloid science, nanotechnology, biomaterials, and liquid crystals. Students taking graduate version complete additional assignments.
B. D. Olsen

10.568 Physical Chemistry of Polymers
Prereq: 5.60, 10.213, or 10.40
G (Fall, Spring)
3-0-6 units

Introduction to polymer science from a molecular perspective. Covers topics in macromolecular confirmation and spatial extent, polymer solution thermodynamics and the theta state, linear viscoelasticity, rubber elasticity, and the thermodynamics and kinetics of formation of glasses and semicrystalline solids. Also provides a basic introduction to dynamics of macromolecules in solutions and melts, with entanglements. Presents methods for characterizing the molecular structure of polymers.
G. C. Rutledge, A. Alexander-Katz

10.569 Synthesis of Polymers
Prereq: 5.12
G (Spring)
3-0-6 units

Studies synthesis of polymeric materials, emphasizing interrelationships of chemical pathways, process conditions, and microarchitecture of molecules produced. Chemical pathways include traditional approaches such as anionic, radical condensation, and ring-opening polymerizations. New techniques, including stable free radicals and atom transfer free radicals, new catalytic approaches to well-defined architectures, and polymer functionalization in bulk and at surfaces. Process conditions include bulk, solution, emulsion, suspension, gas phase, and batch vs continuous fluidized bed. Microarchitecture includes tacticity, molecular-weight distribution, sequence distributions in copolymers, errors in chains such as branches, head-to-head addition, and peroxide incorporation.
P. T. Hammond, B. D. Olsen

10.571[J] Atmospheric Physics and Chemistry
Same subject as 12.806[J]
Subject meets with 12.306
Prereq: (18.075 and (5.60 or 5.61)) or permission of instructor
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Spring)
3-0-9 units

See description under subject 12.806[J].
R. G. Prinn

10.579[J] Energy Technology and Policy: From Principles to Practice
Same subject as 5.00[J], 6.929[J], 22.813[J]
Prereq: None
G (Spring)
Not offered regularly; consult department
3-0-6 units

Develops analytical skills to lead a successful technology implementation with an integrated approach that combines technical, economical and social perspectives. Considers corporate and government viewpoints as well as international aspects, such as nuclear weapons proliferation and global climate issues. Discusses technologies such as oil and gas, nuclear, solar, and energy efficiency. Limited to 100.
J. Deutch

10.580 Solid-State Surface Science
Prereq: 10.213
G (Fall)
Not offered regularly; consult department
3-0-6 units

Structural, chemical, and electronic properties of solids and solid surfaces. Analytical tools used to characterize surfaces including Auger and photoelectron spectroscopies and electron diffraction techniques. Surface thermodynamics and kinetics including adsorption-desorption, catalytic properties, and sputtering processes. Applications to microelectronics, optical materials, and catalysis.
K. K. Gleason

10.585 Engineering Nanotechnology
Prereq: 10.213, 10.302, or permission of instructor
G (Fall)
3-0-9 units

Review of fundamental concepts of energy, mass and electron transport in materials confined or geometrically patterned at the nanoscale, where departures from classical laws are dominant. Specific applications to contemporary engineering challenges are discussed including problems in energy, biology, medicine, electronics, and material design.
M. Strano

10.586 Crystallization Science and Technology
Prereq: 10.213
Acad Year 2018-2019: G (Fall)
Acad Year 2019-2020: Not offered
3-0-6 units

Studies the nucleation and growth of crystals from a melt or a liquid solution and their important role in a wide range of applications, including pharmaeuticals, proteins, and semiconductor materials. Provides background information and covers topics needed to understand, perform experiments, construct and simulate mechanistic models, and design, monitor, and control crystallization processes. Limited to 30.
A. S. Myerson

10.591 Case Studies in Bioengineering
Prereq: Biology (GIR) or permission of instructor
G (Fall)
3-0-6 units

Analysis and discussion of recent research in areas of bioengineering, including drug delivery, protein and tissue engineering, physiological transport, stem cell technology, and quantitative immunology by senior investigators in the Boston area. Students will read and critique papers, then have discussions with authors about their work.
C. K. Colton

10.595 Molecular Design and Bioprocess Development of Immunotherapies
Subject meets with 10.495
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-6 units

Examines challenges and opportunities for applying chemical engineering principles to address the growing global burden of infectious disease, including drug-resistant strains and neglected pathogens. Topics include a historical overview of vaccines and immunotherapies, the molecular design considerations for new immunotherapies and adjuvants, the economic challenges for process development and manufacturing of immunotherapies, and new technologies for designing and assessing therapies. Case studies to cover topics for specific diseases. Students taking graduate version complete additional assignments.
J. C. Love

10.606 Picturing Science and Engineering
Prereq: None
G (Spring; second half of term)
1-2-2 units

Provides instruction in best practices for creating more effective graphics and photographs to support and communicate research in science and engineering. Discusses in depth specific examples from a range of scientific contexts, such as journal articles, presentations, grant submissions, and cover art. Topics include graphics for figures depicting form and structure, process, and change over time. Prepares students to create effective graphics for submissions to existing journals and calls attention to the future of published graphics with the advent of interactivity. Limited to 10.
F. Frankel

10.625[J] Electrochemical Energy Conversion and Storage: Fundamentals, Materials and Applications
Same subject as 2.625[J]
Prereq: 2.005, 3.046, 3.53, 10.40, (2.051 and 2.06), or permission of instructor
G (Fall)
4-0-8 units

See description under subject 2.625[J].
Y. Shao-Horn

10.626 Electrochemical Energy Systems
Subject meets with 10.426
Prereq: 10.50 or permission of instructor
G (Spring)
3-0-9 units

Introduces electrochemical energy systems from the perspective of thermodynamics, kinetics, and transport. Surveys analysis and design of electrochemical reactions and processes by integrating chemical engineering fundamentals with knowledge from diverse fields, including chemistry, electrical engineering, and materials science. Includes applications to fuel cells, electrolyzers, and batteries. Students taking graduate version complete additional assignments.
K. Manthiram

10.631 Structural Theories of Polymer Fluid Mechanics
Prereq: 10.301
G (Spring)
Not offered regularly; consult department
3-0-6 units

Structural and molecular models for polymeric liquids. Nonequilibrium properties are emphasized. Elementary kinetic theory of polymer solutions. General phase space kinetic for polymer melts and solutions. Network theories. Interrelations between structure and rheological properties.
R. C. Armstrong

10.637[J] Quantum Chemical Simulation
Same subject as 5.698[J]
Subject meets with 5.697[J], 10.437[J]
Prereq: None
G (Fall)
3-0-9 units

Addresses both the theory and application of first-principles computer simulations methods (i.e., quantum, chemical, or electronic structure), including Hartree-Fock theory, density functional theory, and correlated wavefunction methods. Covers enhanced sampling, ab initio molecular dynamics, and transition-path-finding approaches as well as errors and accuracy in total and free energies. Discusses applications such as the study and prediction of properties of chemical systems, including heterogeneous, molecular, and biological catalysts (enzymes), and physical properties of materials. Students taking graduate version complete additional assignments.
H. J. Kulik

10.643[J] Future Medicine: Drug Delivery, Therapeutics, and Diagnostics
Same subject as HST.526[J]
Subject meets with 10.443
Prereq: 5.12 or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-6 units

Aims to describe the direction and future of medical technology. Introduces pharmaceutics, pharmacology, and conventional medical devices, then transitions to drug delivery systems, mechanical/electric-based and biological/cell-based therapies, and sensors. Covers nano- and micro drug delivery systems, including polymer-drug conjugates, protein therapeutics, liposomes and polymer nanoparticles, viral and non-viral genetic therapy, and tissue engineering. Previous coursework in cell biology and organic chemistry recommended. Students taking graduate version complete additional assignments. Limited to 40.
D. G. Anderson

10.644[J] Frontiers in Therapeutics and Drug Delivery
Same subject as HST.914[J]
Prereq: 7.05 or permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-6 units

Provides an introduction to pharmaceutics and conventional oral, injected, transdermal and inhaled drug delivery systems. Includes studies of drug delivery devices and systems, e.g., stents, pumps, depo systems, responsive drug delivery systems, and biological/cell based therapies. Covers nano- and micro drug delivery systems, including polymer-drug conjugates, modified proteins, liposomes and polymer nanoparticles, viral and non-viral genetic therapy, and microencapsulated vaccines. Discusses reviews and current technology. Students taking graduate version complete additional assignments. Limited to 40.
D. G. Anderson

10.65 Chemical Reactor Engineering
Prereq: 10.37 or permission of instructor
G (Spring)
4-0-8 units

Fundamentals of chemically reacting systems with emphasis on synthesis of chemical kinetics and transport phenomena. Topics include kinetics of gas, liquid, and surface reactions; quantum chemistry; transition state theory; surface adsorption, diffusion, and desorption processes; mechanism and kinetics of biological processes; mechanism formulation and sensitivity analysis. Reactor topics include nonideal flow reactors, residence time distribution and dispersion models; multiphase reaction systems; nonlinear reactor phenomena. Examples are drawn from different applications, including heterogeneous catalysis, polymerization, combustion, biochemical systems, and materials processing.
M. Strano, G. Stephanopoulos

10.652[J] Kinetics of Chemical Reactions
Same subject as 5.68[J]
Prereq: 5.62, 10.37, or 10.65
Acad Year 2018-2019: G (Fall)
Acad Year 2019-2020: Not offered
3-0-6 units

See description under subject 5.68[J].
W. H. Green

10.668[J] Statistical Mechanics of Polymers
Same subject as 3.941[J]
Prereq: 10.568 or permission of instructor
G (Fall)
3-0-9 units

Concepts of statistical mechanics and thermodynamics applied to macromolecules: polymer conformations in melts, solutions, and gels; Rotational Isomeric State theory, Markov processes and molecular simulation methods applied to polymers; incompatibility and segregation in incompressible and compressible systems; molecular theory of viscoelasticity; relation to scattering and experimental measurements.
G. C. Rutledge, A. Alexander-Katz

10.677 Topics in Applied Microfluidics
Prereq: 10.301 or permission of instructor
G (Fall)
3-0-6 units

Provides an introduction to the field of microfluidics. Reviews fundamental concepts in transport phenomena and dimensional analysis, focusing on new phenomena which arise at small scales. Discusses current applications, with an emphasis on the contributions engineers bring to the field. Local and visiting experts in the field discuss their work. Limited to 30.
P. Doyle

10.689 Concepts in Modern Heterogeneous Catalysis
Subject meets with 10.489
Prereq: 10.302 and 10.37
G (Spring)
Not offered regularly; consult department
3-0-6 units

Explores topics in the design and implementation of heterogeneous catalysts for chemical transformations. Emphasizes use of catalysis for environmentally benign and sustainable chemical processes. Lectures address concepts in catalyst preparation, catalyst characterization, quantum chemical calculations, and microkinetic analysis of catalytic processes. Shows how experimental and theoretical approaches can illustrate important reactive intermediates and transition states involved in chemical reaction pathways, and uses that information to help identify possible new catalysts that may facilitate reactions of interest. Draws examples from current relevant topics in catalysis. Includes a group project in which students investigate a specific topic in greater depth. Students taking graduate version complete additional assignments.
Y. Roman

10.702[J] Introduction to Experimental Biology and Communication
Same subject as 7.02[J]
Prereq: Biology (GIR)
U (Fall, Spring)
4-8-6 units. Institute LAB

Introduction to the experimental concepts and methods of molecular biology, biochemistry, and genetic analysis. Emphasis on experimental design, critical data analysis, and the development of written communications skills. 12 units may be applied to the General Institute Laboratory Requirement. Enrollment limited.
E. Calo-Velazquez, M. Gehring, T. Schwartz, O. Yilmaz, K. D. Wittrup

10.792[J] Global Operations Leadership Seminar
Same subject as 2.890[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

10.805[J] Technology, Law, and the Working Environment
Same subject as IDS.436[J]
Subject meets with 1.802[J], 1.812[J], 11.022[J], 11.631[J], IDS.061[J], IDS.541[J]
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-6 units

See description under subject IDS.436[J].
N. A. Ashford, C. C. Caldart

10.806 Management in Engineering
Engineering School-Wide Elective Subject.
Offered under: 2.96, 6.930, 10.806, 16.653
Prereq: None
U (Fall)
3-1-8 units

See description under subject 2.96. Restricted to juniors and seniors.
H. S. Marcus, J.-H. Chun

10.807[J] Innovation Teams
Same subject as 15.371[J]
Prereq: 15.911 or permission of instructor
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall, Spring)
4-4-4 units

Introduces skills and capabilities for systematic technical and functional exploration, opportunity discovery, market understanding, value economics, innovation scale-up, intellectual property, elements of technology commercialization at scale, and communicating/working for impact inside and outside home disciplines. Students work in multidisciplinary teams formed around MIT research breakthroughs, with extensive in-class coaching from faculty and guidance from lab members and select mentors. Demonstrates a structured approach to innovating in which everything is a variable and the product, technology, and opportunities for new ventures can be seen as an act of synthesis. Teams gather evidence that permits a fact-based iteration across multiple application domains, markets, functionalities, technologies, and products, leading to a recommendation that maps a space of opportunity and includes actionable next steps to evolve the market and technology. Applications, resumes, and a brief statement of interest are required prior to registration.
F. Murray, L. Perez-Breva

10.817[J] Atmospheric Chemistry
Same subject as 1.84[J], 12.807[J]
Prereq: 5.60
Acad Year 2018-2019: Not offered
Acad Year 2019-2020: G (Fall)
3-0-9 units

See description under subject 1.84[J].
J. H. Kroll

School of Chemical Engineering Practice

10.80 (10.82, 10.84, 10.86) School of Chemical Engineering Practice -- Technical Accomplishment
Prereq: None
G (Fall, Spring, Summer)
0-6-0 units

Conducted at industrial field stations of the School of Chemical Engineering Practice. Group problem assignments include process development design, simulation and control, technical service, and new-product development. Grading based on technical accomplishment. Credit granted in lieu of master's thesis. See departmental descripton on School of Chemical Engineering Practice for details. Enrollment limited and subject to plant availability.
T. A. Hatton

10.81 (10.83, 10.85, 10.87) School of Chemical Engineering Practice -- Communication Skills and Human Relations
Prereq: None
G (Fall, Spring, Summer)
0-6-0 units

Conducted at industrial field stations of the School of Chemical Engineering Practice. Group problem assignments include process development, design, simulation and control, technical service, and new-product development. Grading based on communication skills and human relations in group assignments. Credit granted in lieu of master's thesis; see departmental description on School of Chemical Engineering Practice for details. Enrollment limited and subject to plant availability.
T. A. Hatton

General

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

For special and graduate students who wish to carry out some minor investigation in a particular field. Subject and hours to fit individual requirements.
R. D. Braatz

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

For undergraduate students who wish to carry out a special investigation in a particular field. Topic and hours arranged.
B. S. Johnston

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

For undergraduate students who wish to carry out a special investigation in a particular field. Topic and hours arranged.
B. S. Johnston

10.912 Practical Internship in Chemical Engineering
Prereq: None
U (Fall, IAP, Spring, Summer)
0-1-0 units

Provides academic credit for professional experiences in chemical engineering at external facilities, such as companies or laboratories. At the end of the internship, students must submit a report that describes the experience, details their accomplishments, and synthesizes the perspectives, knowledge, and skills to be carried forward into the rest of their studies.
B. S. Johnston

10.953 Seminar in Heterogeneous Catalysis
Prereq: None
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Students present their research to other students and staff. Research topics include heterogeneous catalysis, design of catalytic materials, biomass conversion, biofuels, and CO_2 utilization.
Y. Roman

10.954 Seminar in Applied Optical Spectroscopy
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Research seminars given by students, postdocs, and visitors. Topics covered include applied optical spectroscopy and imaging, with particular emphasis on nanomaterials and how they relate to alternative energy technologies.
W. A. Tisdale

10.955 Seminar in Electrochemical Engineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Designed to allow students to present and discuss their research in the area of electrochemical engineering with a particular emphasis on energy storage and conversion (e.g., batteries, fuel cells, electroreactors). Specific topics include active materials design, electroanalytical platform development, and integration of electrochemical and imaging techniques.
F. R. Brushett

10.956 Seminar in Atomistic Simulation
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Seminar allows students to present their research to other students and staff. The research topics include electronic structure theory, computational chemistry techniques, and density functional theory with a focus on applications to catalysis and materials science.
H. J. Kulik

10.957 Seminar in Bioengineering Technology
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Research seminars presented by students and guest speakers on emerging biotechnologies.
K. Chung

10.958 Seminar in the Fluid Mechanics and Self-assembly of Soft Matter
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Covers topics related to low Reynolds number hydrodynamics and the statistical physics of particulate media. Specifics include the kinetics of phase transitions in soft matter and the time-varying deformation of colloidal dispersions, glasses and gels.
J. W. Swan

10.960[J] Seminar in Polymers and Soft Matter
Same subject as 3.903[J]
Prereq: None
G (Fall, Spring)
2-0-0 units
Can be repeated for credit.

A series of seminars covering a broad spectrum of topics in polymer science and engineering, featuring both on- and off-campus speakers.
A. Alexander-Katz, R. E. Cohen, D. Irvine

10.961 Seminar in Advanced Air Pollution Research
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

Research seminars, presented by students engaged in thesis work in the field of air pollution. Particular emphasis given to atmospheric chemistry, mathematical modeling, and policy analysis.
G. J. McRae

10.962 Seminar in Molecular Cell Engineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Weekly seminar with discussion of ongoing research and relevant literature by graduate students, postdoctoral fellows, and visiting scientists on issues at the interface of chemical engineering with molecular cell biology. Emphasis is on quantitative aspects of physicochemical mechanisms involved in receptor/ligand interactions, receptor signal transduction processes, receptor-mediated cell behavioral responses, and applications of these in biotechnology and medicine.
D. A. Lauffenburger

10.964 Seminar on Transport Theory
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Research seminars presented by students and guest speakers on mathematical modeling of transport phenomena, focusing on electrochemical systems, electrokinetics, and microfluidics.
M. Z. Bazant

10.965 Seminar in Biosystems Engineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Advanced topics on the state-of-the-art in design and implementation of analytical processes for biological systems, including single-cell analysis, micro/nanotechnologies, systems biology, biomanufacturing, and process engineering. Seminars and discussions guided by the research interests of participating graduate students, postdoctoral associates, faculty, and visiting lecturers.
J. C. Love

10.966 Seminar in Drug Delivery, Biomaterials, and Tissue Engineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Focuses on presentations by students and staff on current research in the area of drug delivery, biomaterials, and tissue engineering. Includes topics such as nanotherapeutics, intracellular delivery, and therapies for diabetes.
D. G. Anderson

10.967 Seminar in Protein-Polymer Materials Engineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Research seminar covers topics on protein-based polymeric materials. Specific topics include bioelectronic materials, protein-polymer hybrids, and nanostructured proteins and polymers.
B. D. Olsen

10.968 Seminar in Biomolecular Engineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Covers research progress in the area of design, testing and mechanistic investigation of novel molecular systems for biotechnological applications.
H. D. Sikes

10.969 Molecular Engineering Seminar
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Seminar allows students to present their research to other students and staff. Research topics include molecular simulations techniques and applications, and molecular engineering of pharmaceutical and biopharmaceutical processes and formulations.
B. L. Trout

10.970 Seminar in Molecular Computation
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Seminar allows students to present their research to other students and staff. The research topics include computational chemistry techniques, kinetics, and catalysis. Focus is on molecular-level understanding of chemical change.
W. H. Green

10.971 Seminar in Fluid Mechanics and Transport Phenomena
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Seminar series on current research on Newtonian and non-Newtonian fluid mechanics and transport phenomena, and applications to materials processing. Seminars given by guest speakers and research students.
P. S. Doyle, G. H. McKinley, J. W. Swan

10.972 Biochemical Engineering Research Seminar
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

Seminar allows students to present their research programs to other students and staff. The research topics include fermentation and enzyme technology, mammalian and animal cell cultivation, and biological product separation.
D. I. C. Wang, C. L. Cooney

10.973 Bioengineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Seminar covering topics related to current research in the application of chemical engineering principles to biomedical science and biotechnology.
C. K. Colton

10.974 Seminar in Chemical Engineering Nanotechnology
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Seminar covering topics related to current research in the application of chemical engineering principles to nanotechnology. Limited to 30.
M. S. Strano

10.975 Seminar in Polymer Science and Engineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Research seminars, presented by students engaged in thesis work in the field of polymers and by visiting lecturers from industry and academia.
R. E. Cohen, P. T. Hammond, G. C. Rutledge

10.976 Process Design, Operations, and Control
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Seminars on the state of the art in design, operations, and control of processing systems, with emphasis on computer-based tools. Discussions guided by the research interests of participating students. Topics include mathematical and numerical techniques, representational methodologies, and software development.
P. I. Barton

10.977 Seminar in Electrocatalysis
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Seminar held every week, with presentations by graduate students and postdoctoral researchers on topics related to the molecular engineering of electrocatalysts. Emphasis on correlating atomic-level understanding of surfaces, their interactions with adsorbates, and the resulting impact on catalytic mechanisms.
K. Manthiram

10.978 Seminar in Advanced Materials for Energy Applications
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Students, postdocs, and visitors to present their work on synthesis, design, and characterization of polymeric and inorganic materials for applications related to membrane and adsorption-based separations.
Z. P. Smith

10.981 Seminar in Colloid and Interface Science
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Review of current topics in colloid and interface science. Topics include statistical mechanics and thermodynamics of micellar solutions, self-assembling systems, and microemulsions; solubilization of simple ions, amino acids, and proteins in reversed micelles; enzymatic reactions in reversed micelles; phase equilibria in colloidal systems; interfacial phenomena in colloidal systems; biomedical aspects of colloidal systems.
D. Blankschtein

10.982 Seminar in Experimental Colloid and Surface Chemistry
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

In-depth discussion of fundamental physical relationships underlying techniques commonly used in the study of colloids and surfaces with a focus on recent advances and experimental applications. Topics have included the application of steady-state and time-resolved fluorescence spectroscopies, infrared spectroscopy, and scanning probe microscopies.
T. A. Hatton

10.983 Reactive Processing and Microfabricated Chemical Systems
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Advanced topics in synthesis of materials through processes involving transport phenomena and chemical reactions. Chemical vapor deposition, modeling, and experimental approaches to kinetics of gas phase and surface reactions, transport phenomena in complex systems, materials synthesis, and materials characterization. Design fabrication and applications of microfabricated chemical systems. Seminars by graduate students, postdoctoral associates, participating faculty, and visiting lecturers.
K. F. Jensen

10.984 Biomedical Applications of Chemical Engineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Weekly seminar with lectures on current research by graduate students, postdoctoral fellows, and visiting scientists on topics related to biomedical applications of chemical engineering. Specific topics include polymeric controlled release technology, extracorporal reactor design, biomedical polymers, bioengineering aspects of pharmaceuticals, and biomaterials/tissue and cell interactions.
R. S. Langer

10.985 Advanced Manufacturing Seminar
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Focuses on the state of the art in the systems engineering of materials products and materials manufacturing processes. Addresses topics such as pharmaceuticals manufacturing, polymeric drug delivery systems, and nano- and microstructured materials. Discussions guided by the research interests of participating students. Includes techniques from applied mathematics and numerical methods, multiscale systems analysis, and control theory.
R. D. Braatz

10.987 Solid Thin Films and Interfaces
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Current research topics and fundamental issues relating to the deposition and properties of solid thin films and interfaces. Emphasis on applying analytical techniques, such as solid-state NMR, to explore the thermodynamics and kinetics of growth, defect formation, and structural modification incurred during film growth and post processing.
K. K. Gleason

10.989 Seminar in Biotechnology
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Research seminars, presented by graduate students and visitors from industry and academia, covering a broad range of topics of current interest in biotechnology. Discussion focuses on generic questions with potential biotechnological applications and the quest for solutions through a coordinated interdisciplinary approach.
Gr. Stephanopoulos

10.990 Introduction to Chemical Engineering Research
Prereq: None
G (Fall)
2-4-0 units

Introduction to research in chemical engineering by faculty of chemical engineering department. Focus is on recent developments and research projects available to new graduate students.
P. T. Hammond

10.991 Seminar in Chemical Engineering
Prereq: Permission of instructor
G (Fall)
2-0-4 units
Can be repeated for credit.

For students working on doctoral theses.
P. T. Hammond

10.992 Seminar in Chemical Engineering
Prereq: Permission of instructor
G (Spring)
2-0-4 units
Can be repeated for credit.

For students working on doctoral theses.
K. F. Jensen

10.994 Molecular Bioengineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Presentations and discussion by graduate students, postdoctoral fellows, and visiting scientists of current literature and research on the engineering of protein biopharmaceuticals. Topics include combinatorial library construction and screening strategies, antibody engineering, gene therapy, cytokine engineering, and immunotherapy engineering strategies.
K. D. Wittrup

10.995 Cellular and Metabolic Engineering
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Graduate students, postdoctoral fellows, visiting scientists, and guest industrial practitioners to present their own research and highlight important advances from the literature in biochemical and bioprocess engineering. Topics of interest include metabolic engineering, novel microbial pathway design and optimization, synthetic biology, and applications of molecular biology to bioprocess development.
K. J. Prather

10.997 Theoretical and Computational Immunology Seminar
Prereq: Permission of instructor
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Presentations and discussions of current literature and research in theoretical and computational immunology. Topics include T cell biology, cell-cell recognition in immunology, polymers and membranes, and statistical mechanics.
A. K. Chakraborty

10.998 Seminar in Crystallization Science and Technology
Prereq: None
G (Fall, Spring)
2-0-4 units
Can be repeated for credit.

Focuses on current topics related to crystallization science and technology in the chemical, pharmaceutical and food industries. Discusses fundamental work on nucleation, polymorphism, impurity crystal interactions and nano-crystal formation, along with industrial applications of crystallization.
A. S. Myerson

10.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: 2.EPW or permission of instructor
U (Fall, Spring)
0-0-1 units

See description under subject 2.EPE.
Staff

10.EPW UPOP Engineering Practice Workshop
Engineering School-Wide Elective Subject.
Offered under: 1.EPW, 2.EPW, 3.EPW, 6.EPW, 10.EPW, 16.EPW, 20.EPW, 22.EPW
Prereq: None
U (Fall, IAP)
1-0-0 units

See description under subject 2.EPW. Enrollment limited.
Staff

10.S94 Special Problems in Chemical Engineering
Prereq: Permission of instructor
U (Fall, Spring)
Units arranged
Can be repeated for credit.

Focuses on problem of current interest not covered in regular curriculum; topic varies from year to year.
Staff

10.S95 Special Problems in Chemical Engineering
Prereq: Permission of instructor
G (Fall, Spring)
Units arranged
Can be repeated for credit.

Focuses on problem of current interest not covered in regular curriculum; topic varies from year to year.
Staff

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

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

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

Program of research leading to writing an SB thesis; topic arranged between student and MIT faculty member.
B. S. Johnston

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

Opportunity for participation in the work of a research group, or for special investigation in a particular field. Topic and hours to fit individual requirements.
B. S. Johnston

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

Opportunity for participation in a research group, or for special investigation in a particular field. Topic and hours to fit individual requirements.
B. S. Johnston