Undergraduate Subjects

8.01 Physics I
Prereq: None
U (Fall)
3-2-7 units. PHYSICS I
Credit cannot also be received for 8.011, 8.012, 8.01L, ES.801
Introduces classical mechanics. Space and time: straight-line kinematics; motion in a plane; forces and static equilibrium; particle dynamics, with force and conservation of momentum; relative inertial frames and non-inertial force; work, potential energy and conservation of energy; kinetic theory and the ideal gas; rigid bodies and rotational dynamics; vibrational motion; conservation of angular momentum; central force motions; fluid mechanics. Subject taught using the TEAL (Technology-Enabled Active Learning) format which features students working in groups of three, discussing concepts, solving problems, and doing table-top experiments with the aid of computer data acquisition and analysis.
J. Formaggio, P. Dourmashkin

8.011 Physics I
Prereq: None
U (Spring)
5-0-7 units. PHYSICS I
Credit cannot also be received for 8.01, 8.012, 8.01L, ES.801
Introduces classical mechanics. Space and time: straight-line kinematics; motion in a plane; forces and equilibrium; experimental basis of Newton's laws; particle dynamics; universal gravitation; collisions and conservation laws; work and potential energy; vibrational motion; conservative forces; inertial forces and non-inertial frames; central force motions; rigid bodies and rotational dynamics. Designed for students with previous experience in 8.01; the subject is designated as 8.01 on the transcript.
D. Pritchard

8.012 Physics I
Prereq: None
U (Fall)
5-0-7 units. PHYSICS I
Credit cannot also be received for 8.01, 8.011, 8.01L, ES.801
Elementary mechanics, presented in greater depth than in 8.01. Newton's laws, concepts of momentum, energy, angular momentum, rigid body motion, and non-inertial systems. Uses elementary calculus freely; concurrent registration in a math subject more advanced than 18.01 is recommended. In addition to covering the theoretical subject matter, students complete a small experimental project of their own design. Freshmen admitted via AP or Math Diagnostic for Physics Placement results.
M. Soljacic

8.01L Physics I
Prereq: None
U (Fall, IAP)
3-2-7 units. PHYSICS I
Credit cannot also be received for 8.01, 8.011, 8.012, ES.801
Introduction to classical mechanics (see description under 8.01). Includes components of the TEAL (Technology-Enabled Active Learning) format. Material covered over a longer interval so that the subject is completed by the end of the IAP. Substantial emphasis given to reviewing and strengthening necessary mathematics tools, as well as basic physics concepts and problem-solving skills. Content, depth, and difficulty is otherwise identical to that of 8.01. The subject is designated as 8.01 on the transcript.
P. Jarillo-Herrero

8.02 Physics II
Prereq: Calculus I (GIR) and Physics I (GIR)
U (Fall, Spring)
3-2-7 units. PHYSICS II
Credit cannot also be received for 8.021, 8.022, ES.802, ES.8022
Introduction to electromagnetism and electrostatics: electric charge, Coulomb's law, electric structure of matter; conductors and dielectrics. Concepts of electrostatic field and potential, electrostatic energy. Electric currents, magnetic fields and Ampere's law. Magnetic materials. Time-varying fields and Faraday's law of induction. Basic electric circuits. Electromagnetic waves and Maxwell's equations. Subject taught using the TEAL (Technology Enabled Active Learning) studio format which utilizes small group interaction and current technology to help students develop intuition about, and conceptual models of, physical phenomena.
J. Belcher, I. Cisse
8.021 Physics II
Prereq: Calculus I (GIR), Physics I (GIR), and permission of instructor
U (Fall)
5-0-7 units. PHYSICS II
Credit cannot also be received for 8.02, 8.022, ES.802, ES.8022
Introduction to electromagnetism and electrostatics: electric charge, Coulomb’s law, electric structure of matter; conductors and dielectrics. Concepts of electrostatic field and potential, electrostatic energy. Electric currents, magnetic fields and Ampere’s law. Magnetic materials. Time-varying fields and Faraday’s law of induction. Basic electric circuits. Electromagnetic waves and Maxwell’s equations. Designed for students with previous experience in 8.02; the subject is designated as 8.02 on the transcript. Enrollment limited.
J. Checkelsky

8.022 Physics II
Prereq: Physics I (GIR); Coreq: Calculus II (GIR)
U (Fall, Spring)
5-0-7 units. PHYSICS II
Credit cannot also be received for 8.02, 8.021, ES.802, ES.8022
Parallel to 8.02, but more advanced mathematically. Some knowledge of vector calculus assumed. Maxwell’s equations, in both differential and integral form. Electrostatic and magnetic vector potential. Properties of dielectrics and magnetic materials. In addition to the theoretical subject matter, several experiments in electricity and magnetism are performed by the students in the laboratory.
D. Harlow

8.03 Physics III
Prereq: Calculus II (GIR) and Physics II (GIR)
U (Fall, Spring)
5-0-7 units. REST
Mechanical vibrations and waves; simple harmonic motion, superposition, forced vibrations and resonance, coupled oscillations, and normal modes; vibrations of continuous systems; reflection and refraction; phase and group velocity. Optics; wave solutions to Maxwell’s equations; polarization; Snell’s Law, interference, Huygens’s principle, Fraunhofer diffraction, and gratings.
Y.-J. Lee, R. Comin

8.033 Relativity
Prereq: Calculus II (GIR) and Physics II (GIR)
U (Fall)
5-0-7 units. REST
Einstein’s postulates; consequences for simultaneity, time dilation, length contraction, and clock synchronization; Lorentz transformation; relativistic effects and paradoxes; Minkowski diagrams; invariants and four-vectors; momentum, energy, and mass; particle collisions. Relativity and electricity; Coulomb’s law; magnetic fields. Brief introduction to Newtonian cosmology. Introduction to some concepts of general relativity; principle of equivalence. The Schwarzschild metric; gravitational red shift; particle and light trajectories; geodesics; Shapiro delay.
S. Vitale

8.04 Quantum Physics I
Prereq: 8.03 and (18.03 or 18.032)
U (Spring)
5-0-7 units. REST
Credit cannot also be received for 8.04
Experimental basis of quantum physics: photoelectric effect, Compton scattering, photons, Franck-Hertz experiment, the Bohr atom, electron diffraction, deBroglie waves, and wave-particle duality of matter and light. Introduction to wave mechanics: Schroedinger’s equation, wave functions, wave packets, probability amplitudes, stationary states, the Heisenberg uncertainty principle, and zero-point energies. Solutions to Schroedinger’s equation in one dimension: transmission and reflection at a barrier, barrier penetration, potential wells, the simple harmonic oscillator. Schroedinger’s equation in three dimensions: central potentials and introduction to hydrogenic systems.
V. Vuletic, M. Vogelsberger

8.04 Special Subject: Quantum Physics I
Prereq: 8.03 and (18.03 or 18.032)
U (Fall)
2-0-10 units. REST
Credit cannot also be received for 8.04
Experimental version of 8.04, which offers a combination of online and in-person instruction. See description of 8.04. Licensed by the Committee on Curricula as an acceptable alternative to 8.04 for Fall 2017.
R. Ashoori
**8.044 Statistical Physics I**
Prereq: 8.03 and 18.03  
U (Spring)  
5-0-7 units

Introduction to probability, statistical mechanics, and thermodynamics. Random variables, joint and conditional probability densities, and functions of a random variable. Concepts of macroscopic variables and thermodynamic equilibrium, fundamental assumption of statistical mechanics, microcanonical and canonical ensembles. First, second, and third laws of thermodynamics. Numerous examples illustrating a wide variety of physical phenomena such as magnetism, polyatomic gases, thermal radiation, electrons in solids, and noise in electronic devices. Concurrent enrollment in 8.04 is recommended.  
_N. Fakhri_

**8.05 Quantum Physics II**
Prereq: 8.04  
U (Fall)  
5-0-7 units  
Credit cannot also be received for 8.051

Fall: Staff  
Spring: W. Detmold

**8.051 Quantum Physics II**
Prereq: 8.04 and permission of instructor  
U (Spring)  
2-0-10 units  
Credit cannot also be received for 8.05  
Fall: Staff  
Spring: W. Detmold

**8.06 Quantum Physics III**
Prereq: 8.05  
U (Spring)  
5-0-7 units

Continuation of 8.05. Units: natural units, scales of microscopic phenomena, applications. Time-independent approximation methods: degenerate and nondegenerate perturbation theory, variational method, Born-Oppenheimer approximation, applications to atomic and molecular systems. The structure of one- and two-electron atoms: overview, spin-orbit and relativistic corrections, fine structure, variational approximation, screening, Zeeman and Stark effects. Charged particles in a magnetic field: Landau levels and integer quantum hall effect. Scattering: general principles, partial waves, review of one-dimension, low-energy approximations, resonance, Born approximation. Time-dependent perturbation theory. Students research and write a paper on a topic related to the content of 8.05 and 8.06.  
B. Zwiebach
8.07 Electromagnetism II
Prereq: 8.03 and 18.03
U (Fall)
4-0-8 units

A. Guth

8.08 Statistical Physics II
Prereq: 8.044 and 8.05
U (Spring)
4-0-8 units

Fall: Staff
Spring: L. Fu

8.09 Classical Mechanics III
Subject meets with 8.309
Prereq: 8.223
U (Fall)
4-0-8 units

Covers Lagrangian and Hamiltonian mechanics, systems with constraints, rigid body dynamics, vibrations, central forces, Hamilton-Jacobi theory, action-angle variables, perturbation theory, and continuous systems. Provides an introduction to ideal and viscous fluid mechanics, including turbulence, as well as an introduction to nonlinear dynamics, including chaos. Students taking graduate version complete different assignments.
I. Stewart

Undergraduate Laboratory and Special Project Subjects

8.13 Experimental Physics I
Prereq: 8.04
U (Fall, Spring)
0-6-12 units. Institute LAB

Four fundamental laboratory experiments are carried out each term, covering most aspects of modern physics relating to names such as Rutherford, Franck-Hertz, Hall, Ramsauer, Doppler, Fraunhofer, Faraday, Mossbauer, Compton, and Stern-Gerlach. Stresses basic experimental techniques and data analysis, and written and oral presentation of experiment results.
J. Conrad, J. Formaggio, A. Levine, K. Perez

8.14 Experimental Physics II
Prereq: 8.05 and 8.13
U (Spring)
0-6-12 units

Four fundamental laboratory experiments are carried out each term, covering most aspects of modern physics relating to names such as Rutherford, Franck-Hertz, Hall, Ramsauer, Doppler, Fraunhofer, Faraday, Mossbauer, Compton, and Stern-Gerlach. Stresses basic experimental techniques and data analysis, and written and oral presentation of experiment results. 8.14 requires knowledge of quantum mechanics at the 8.05 level.
G. Roland

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

Opportunity for undergraduates to engage in experimental or theoretical research under the supervision of a staff member. Specific approval required in each case.
Consult N. Mavalvala

8.19 Readings in Physics
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Supervised reading and library work. Choice of material and allotment of time according to individual needs. For students who want to do work not provided for in the regular subjects. Specific approval required in each case.
Consult N. Mavalvala
Undergraduate Elective Subjects

8.20 Introduction to Special Relativity
Prereq: Calculus I (GIR) and Physics I (GIR)
U (IAP)
2-0-7 units. REST

Introduces the basic ideas and equations of Einstein’s special theory of relativity. Topics include Lorentz transformations, length contraction and time dilation, four vectors, Lorentz invariants, relativistic energy and momentum, relativistic kinematics, Doppler shift, space-time diagrams, relativity paradoxes, and some concepts of general relativity. Intended for freshmen and sophomores. Not usable as a restricted elective by Physics majors. Credit cannot be received for 8.20 if credit for 8.033 is or has been received in the same or prior terms.
S. Vitale

8.21 Physics of Energy
Prereq: Calculus II (GIR), Chemistry (GIR), and Physics II (GIR)
U (Spring)
5-0-7 units. REST

A comprehensive introduction to the fundamental physics of energy systems that emphasizes quantitative analysis. Focuses on the fundamental physical principles underlying energy processes and on the application of these principles to practical calculations. Applies mechanics and electromagnetism to energy systems; introduces and applies basic ideas from thermodynamics, quantum mechanics, and nuclear physics. Examines energy sources, conversion, transport, losses, storage, conservation, and end uses. Analyzes the physics of side effects, such as global warming and radiation hazards. Provides students with technical tools and perspective to evaluate energy choices quantitatively at both national policy and personal levels.
R. Jaffe

8.223 Classical Mechanics II
Prereq: Calculus II (GIR) and Physics I (GIR)
U (IAP)
2-0-4 units

A broad, theoretical treatment of classical mechanics, useful in its own right for treating complex dynamical problems, but essential to understanding the foundations of quantum mechanics and statistical physics. Generalized coordinates, Lagrangian and Hamiltonian formulations, canonical transformations, and Poisson brackets. Applications to continuous media. The relativistic Lagrangian and Maxwell’s equations.
Staff, M. Evans

8.224 Exploring Black Holes: General Relativity and Astrophysics
Prereq: 8.033 or 8.20
U (Spring)
Not offered regularly; consult department
3-0-9 units

Study of physical effects in the vicinity of a black hole as a basis for understanding general relativity, astrophysics, and elements of cosmology. Extension to current developments in theory and observation. Energy and momentum in flat space-time; the metric; curvature of space-time near rotating and nonrotating centers of attraction; trajectories and orbits of particles and light; elementary models of the Cosmos. Weekly meetings include an evening seminar and recitation. The last third of the term is reserved for collaborative research projects on topics such as the Global Positioning System, solar system tests of relativity, descending into a black hole, gravitational lensing, gravitational waves, Gravity Probe B, and more advanced models of the cosmos. Subject has online components that are open to selected MIT alumni. Alumni wishing to participate should contact Professor Bertschinger at edbert@mit.edu. Limited to 40.
E. Bertschinger

8.225(J) Einstein, Oppenheimer, Feynman: Physics in the 20th Century
Same subject as STS.042(J)
Prereq: None
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (Fall)
3-0-9 units. HASS-H

See description under subject STS.042[J]. Enrollment limited.
D. I. Kaiser

8.226 Forty-three Orders of Magnitude
Prereq: (8.04 and 8.044) or permission of instructor
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (Spring)
3-0-9 units

Examines the widespread societal implications of current scientific discoveries in physics across forty-three orders of magnitude in length scale. Addresses topics ranging from climate change to nuclear nonproliferation. Students develop their ability to express concepts at a level accessible to the public and to present a well-reasoned argument on a topic that is a part of the national debate. Requires diverse writing assignments, including substantial papers. Enrollment limited.
J. Conrad
8.231 Physics of Solids I
Prereq: 8.044; Coreq: 8.05
U (Fall)
4-0-8 units

Introduction to the basic concepts of the quantum theory of solids. Topics: periodic structure and symmetry of crystals; diffraction; reciprocal lattice; chemical bonding; lattice dynamics, phonons, thermal properties; free electron gas; model of metals; Bloch theorem and band structure, nearly free electron approximation; tight binding method; Fermi surface; semiconductors, electrons, holes, impurities; optical properties, excitons; and magnetism.
S. Todadri

8.241 Introduction to Biological Physics
Subject meets with 20.315, 20.415
Prereq: Physics II (GIR) and (5.60 or 8.044)
U (Spring)
4-0-8 units

Introduces the main concepts of biological physics, with a focus on biophysical phenomena at the molecular and cellular scales. Presents the role of entropy and diffusive transport in living matter; challenges to life resulting from the highly viscous environment present at microscopic scales, including constraints on force, motion and transport within cells, tissues, and fluids; principles of how cellular machinery (e.g., molecular motors) can convert electro-chemical energy sources to mechanical forces and motion. Also covers polymer physics relevant to DNA and other biological polymers, including the study of configurations, fluctuations, rigidity, and entropic elasticity.
I. Cisse

8.251 String Theory for Undergraduates
Prereq: 8.033, 8.044, and 8.05
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (Spring)
4-0-8 units
Credit cannot also be received for 8.821

Introduction to the main concepts of string theory, i.e., quantum mechanics of a relativistic string. Develops aspects of string theory and makes it accessible to students familiar with basic electromagnetism and statistical mechanics, including the study of D-branes and string thermodynamics. Meets with 8.821 when offered concurrently.
H. Liu

8.276 Nuclear and Particle Physics
Prereq: 8.033 and 8.04
U (Spring)
Not offered regularly; consult department
4-0-8 units

Presents a modern view of the fundamental structure of matter. Starting from the Standard Model, which views leptons and quarks as basic building blocks of matter, establishes the properties and interactions of these particles. Explores applications of this phenomenology to both particle and nuclear physics. Emphasizes current topics in nuclear and particle physics research at MIT. Intended for students with a basic knowledge of relativity and quantum physics concepts.
M. Williams

8.277 Introduction to Particle Accelerators
Prereq: (6.013 or 8.07) and permission of instructor
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (Fall, IAP, Spring)
Units arranged
Can be repeated for credit.

Principles of acceleration: beam properties; linear accelerators, synchrotrons, and storage rings. Accelerator technologies: radio frequency cavities, bending and focusing magnets, beam diagnostics. Particle beam optics and dynamics. Special topics: measures of accelerators performance in science, medicine and industry; synchrotron radiation sources; free electron lasers; high-energy colliders; and accelerators for radiation therapy. May be repeated for credit for a maximum of 12 units.
W. Barletta

8.282[J] Introduction to Astronomy
Same subject as 12.402[J]
Prereq: Physics I (GIR)
U (Spring)
3-0-6 units. REST

Quantitative introduction to physics of the solar system, stars, interstellar medium, the galaxy, and universe, as determined from a variety of astronomical observations and models. Topics: planets, planet formation; stars, the Sun, ”normal” stars, star formation; stellar evolution, supernovae, compact objects (white dwarfs, neutron stars, and black holes), pulsars, binary x-ray sources; star clusters, globular and open clusters; interstellar medium, gas, dust, magnetic fields, cosmic rays; distance ladder; galaxies, normal and active galaxies, jets; gravitational lensing; large scaling structure; Newtonian cosmology, dynamical expansion and thermal history of the universe; cosmic microwave background radiation; big bang nucleosynthesis. No prior knowledge of astronomy necessary. Not usable as a restricted elective by Physics majors.
A. Frebel
**8.284 Modern Astrophysics**  
Prereq: 8.04; Coreq: 8.05  
U (Spring)  
3-0-9 units  

Applications of physics (Newtonian, statistical, and quantum mechanics) to fundamental processes that occur in celestial objects. Includes main-sequence stars, collapsed stars (white dwarfs, neutron stars, and black holes), pulsars, supernovae, the interstellar medium, galaxies, and as time permits, active galaxies, quasars, and cosmology. Observational data discussed. No prior knowledge of astronomy is required.  
*N. Weinberg*

**8.286 The Early Universe**  
Prereq: Physics II (GIR) and 18.03  
Acad Year 2019-2020: Not offered  
Acad Year 2020-2021: U (Fall)  
3-0-9 units. REST  

Introduction to modern cosmology. First half deals with the development of the big bang theory from 1915 to 1980, and latter half with recent impact of particle theory. Topics: special relativity and the Doppler effect, Newtonian cosmological models, introduction to non-Euclidean spaces, thermal radiation and early history of the universe, big bang nucleosynthesis, introduction to grand unified theories and other recent developments in particle theory, baryogenesis, the inflationary universe model, and the evolution of galactic structure.  
*A. Guth*

**8.287[J] Observational Techniques of Optical Astronomy**  
Same subject as 12.410[J]  
Prereq: 8.282[J], 12.409, or other introductory astronomy course  
U (Fall)  
3-4-8 units. Institute LAB  

See description under subject 12.410[J]. Limited to 18; preference to Course 8 and Course 12 majors and minors.  
*R. Binzel, A. Bosh*

**8.292[J] Fluid Physics**  
Same subject as 12.330[J]  
Prereq: 5.60, 8.044, or permission of instructor  
U (Spring)  
Not offered regularly; consult department  
3-0-9 units  

A physics-based introduction to the properties of fluids and fluid systems, with examples drawn from a broad range of sciences, including atmospheric physics and astrophysics. Definitions of fluids and the notion of continuum. Equations of state and continuity, hydrostatics and conservation of momentum; ideal fluids and Euler’s equation; viscosity and the Navier-Stokes equation. Energy considerations, fluid thermodynamics, and isentropic flow. Compressible versus incompressible and rotational versus irrotational flow; Bernoulli’s theorem; steady flow, streamlines and potential flow. Circulation and vorticity. Kelvin’s theorem. Boundary layers. Fluid waves and instabilities. Quantum fluids.  
*Staff*

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

For Course 8 students participating in off-campus work experiences in physics. Before registering for this subject, students must have an employment offer from a company or organization and must identify a Physics supervisor. Upon completion of the work, student must submit a letter from the employer describing the work accomplished, along with a substantive final report from the student approved by the MIT supervisor. Subject to departmental approval. Consult departmental academic office.  
*Consult N. Mavalvala*

**8.298 Selected Topics in Physics**  
Prereq: Permission of instructor  
U (Fall, IAP, Spring, Summer)  
Units arranged  
Can be repeated for credit.  

Presentation of topics of current interest, with content varying from year to year.  
*Consult I. Stewart*
8.299 Physics Teaching
Prereq: None
U (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit.

For qualified undergraduate students interested in gaining some experience in teaching. Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview.
Consult N. Mavalvala

8.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

8.S04 Special Subject: Quantum Physics I
Prereq: 8.03 and (18.03 or 18.032)
U (Fall)
2-0-10 units. REST
Credit cannot also be received for 8.04

Experimental version of 8.04, which offers a combination of online and in-person instruction. See description of 8.04. Licensed by the Committee on Curricula as an acceptable alternative to 8.04 for Fall 2017.
R. Ashoori

8.S10 Special Subject: Physics
Prereq: None
U (Spring)
Units arranged
Can be repeated for credit.

Opportunity for group study of subjects in physics not otherwise included in the curriculum.
A. Adams, K. Ellenbogen

8.S30 Special Subject: Physics
Prereq: None
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: U (IAP)
Units arranged

Opportunity for group study of subjects in physics not otherwise included in the curriculum.
A. Bernstein, J. Walsh

8.S50 Special Subject: Physics
Prereq: None
U (IAP)
Units arranged [P/D/F]
Can be repeated for credit.

Opportunity for group study of subjects in physics not otherwise included in the curriculum.
E. Bertschinger

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

Research opportunities in physics. For further information, contact the departmental UROP coordinator.
N. Mavalvala

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

Program of research leading to the writing of an S.B. thesis; to be arranged by the student under approved supervision.
Information: N. Mavalvala

Graduate Subjects

8.309 Classical Mechanics III
Subject meets with 8.09
Prereq: None
G (Fall)
4-0-8 units

Covers Lagrangian and Hamiltonian mechanics, systems with constraints, rigid body dynamics, vibrations, central forces, Hamilton-Jacobi theory, action-angle variables, perturbation theory, and continuous systems. Provides an introduction to ideal and viscous fluid mechanics, including turbulence, as well as an introduction to nonlinear dynamics, including chaos. Students taking graduate version complete different assignments.
I. Stewart
8.311 Electromagnetic Theory I
Prereq: 8.07
G (Spring)
4-0-8 units

Basic principles of electromagnetism: experimental basis, electrostatics, magnetic fields of steady currents, motional emf and electromagnetic induction, Maxwell’s equations, propagation and radiation of electromagnetic waves, electric and magnetic properties of matter, and conservation laws. Subject uses appropriate mathematics but emphasizes physical phenomena and principles.

J. Belcher

Same subject as 18.369[J]
Prereq: 8.07, 18.303, or permission of instructor
Acad Year 2019-2020: G (Spring)
Acad Year 2020-2021: Not offered
3-0-9 units

See description under subject 18.369[J].

S. G. Johnson

8.321 Quantum Theory I
Prereq: 8.05
G (Fall)
4-0-8 units


H. Liu

8.322 Quantum Theory II
Prereq: 8.07 and 8.321
Acad Year 2019-2020: G (Spring)
Acad Year 2020-2021: Not offered
4-0-8 units


S. Todadri

8.323 Relativistic Quantum Field Theory I
Prereq: 8.321
G (Spring)
4-0-8 units


T. Slatyer

8.324 Relativistic Quantum Field Theory II
Prereq: 8.322 and 8.323
G (Fall)
4-0-8 units

The second term of the quantum field theory sequence. Develops in depth some of the topics discussed in 8.323 and introduces some advanced material. Topics: perturbation theory and Feynman diagrams, scattering theory, Quantum Electrodynamics, one loop renormalization, quantization of non-abelian gauge theories, the Standard Model of particle physics, other topics.

T. Slatyer
8.325 Relativistic Quantum Field Theory III
Prereq: 8.324
G (Spring)
4-0-8 units
The third and last term of the quantum field theory sequence. Its aim is the proper theoretical discussion of the physics of the standard model. Topics: quantum chromodynamics; Higgs phenomenon and a description of the standard model; deep-inelastic scattering and structure functions; basics of lattice gauge theory; operator products and effective theories; detailed structure of the standard model; spontaneously broken gauge theory and its quantization; instantons and theta-vacua; topological defects; introduction to supersymmetry.
W. Taylor

8.333 Statistical Mechanics I
Prereq: 8.044 and 8.05
G (Fall)
4-0-8 units
First part of a two-subject sequence on statistical mechanics. Examines the laws of thermodynamics and the concepts of temperature, work, heat, and entropy. Postulates of classical statistical mechanics, microcanonical, canonical, and grand canonical distributions; applications to lattice vibrations, ideal gas, photon gas. Quantum statistical mechanics; Fermi and Bose systems. Interacting systems: cluster expansions, van der Waal’s gas, and mean-field theory.
M. Kardar

8.334 Statistical Mechanics II
Prereq: 8.333
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Spring)
4-0-8 units
Staff

Same subject as 6.946[J], 12.620[J]
Prereq: Physics I (GIR), 18.03, and permission of instructor
G (Fall)
3-3-6 units
See description under subject 12.620[J].
J. Wisdom, G. J. Sussman

8.361 Quantum Theory of Many-Particle Systems
Prereq: 8.322 and 8.333
G (Fall)
Not offered regularly; consult department
3-0-9 units
Introduces general many-body theory applicable to low temperature, nuclear, and solid-state physics. Reviews occupation number representation and classical Mayer expansion. Perturbation theory: diagrammatic expansions and linked-cluster theorem for zero or finite temperature systems of fermions or bosons. Green’s functions: analytic properties, equations of motion, relation to observables, approximations, linear response theory, and random phase approximation. Superconductivity: electron-phonon interaction, instability of normal state, BCS ground state, perturbation theory.
Staff

8.370[J] Quantum Computation
Same subject as 2.111[J], 18.435[J]
Prereq: Permission of instructor
G (Fall)
3-0-9 units
See description under subject 18.435[J].
I. Chuang, A. Harrow, S. Lloyd, P. Shor

8.371[J] Quantum Information Science
Same subject as 6.443[J], 18.436[J]
Prereq: 18.435[J]
G (Spring)
3-0-9 units
Examines quantum computation and quantum information. Topics include quantum circuits, the quantum Fourier transform and search algorithms, the quantum operations formalism, quantum error correction, Calderbank-Shor-Steane and stabilizer codes, fault tolerant quantum computation, quantum data compression, quantum entanglement, capacity of quantum channels, and quantum cryptography and the proof of its security. Prior knowledge of quantum mechanics required.
I. Chuang, A. Harrow

8.381, 8.382 Selected Topics in Theoretical Physics
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units
Topics of current interest in theoretical physics, varying from year to year. Subject not routinely offered; given when sufficient interest is indicated.
Staff
8.391 Pre-Thesis Research
Prereq: Permission of instructor
G (Fall)
Units arranged [P/D/F]
Can be repeated for credit.
Advanced problems in any area of experimental or theoretical physics, with assigned reading and consultations. 
Staff

8.392 Pre-Thesis Research
Prereq: Permission of instructor
G (Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.
Advanced problems in any area of experimental or theoretical physics, with assigned reading and consultations. 
Staff

8.395[J] Teaching College-Level Science and Engineering
Same subject as 1.95[J], 5.95[J], 7.59[J], 18.094[J]
Subject meets with 2.978
Prereq: None
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Fall)
2-0-2 units
See description under subject 5.95[J].
J. Rankin

8.398 Selected Topics in Graduate Physics
Prereq: Permission of instructor
G (Fall, IAP, Spring)
Units arranged
Can be repeated for credit.
Presentation of topics of current interest with content varying from year to year.
Consult N. Mavalvala

8.399 Physics Teaching
Prereq: Permission of instructor
G (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit.
For qualified graduate students interested in gaining some experience in teaching. Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview.
Consult C. Paus

Physics of Atoms, Radiation, Solids, Fluids, and Plasmas

8.421 Atomic and Optical Physics I
Prereq: 8.05
Acad Year 2019-2020: G (Spring)
Acad Year 2020-2021: Not offered
3-0-9 units
The first of a two-term subject sequence that provides the foundations for contemporary research in selected areas of atomic and optical physics. The interaction of radiation with atoms: resonance; absorption, stimulated and spontaneous emission; methods of resonance, dressed atom formalism, masers and lasers, cavity quantum electrodynamics; structure of simple atoms, behavior in very strong fields; fundamental tests: time reversal, parity violations, Bell's inequalities; and experimental methods.
M. Zwierlein

8.422 Atomic and Optical Physics II
Prereq: 8.05
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Spring)
3-0-9 units
The second of a two-term subject sequence that provides the foundations for contemporary research in selected areas of atomic and optical physics. Non-classical states of light- squeezed states; multi-photon processes, Raman scattering; coherence- level crossings, quantum beats, double resonance, superradiance; trapping and cooling: light forces, laser cooling, atom optics, spectroscopy of trapped atoms and ions; atomic interactions-classical collisions, quantum scattering theory, ultracold collisions; and experimental methods.
Staff

8.431[J] Nonlinear Optics
Same subject as 6.634[J]
Prereq: 6.013 or 8.07
G (Spring)
3-0-9 units
See description under subject 6.634[J].
J. G. Fujimoto
8.481, 8.482 Selected Topics in Physics of Atoms and Radiation
Prereq: 8.321
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units

Presentation of topics of current interest, with content varying from year to year. Subject not routinely offered; given when sufficient interest is indicated.

Staff

8.511 Theory of Solids I
Prereq: 8.231
G (Fall)
3-0-9 units
L. Levitov

8.512 Theory of Solids II
Prereq: 8.511
G (Spring)
3-0-9 units
L. Levitov

8.513 Many-Body Theory for Condensed Matter Systems
Prereq: 8.033, 8.05, 8.08, and 8.231
Acad Year 2019-2020: G (Fall)
Acad Year 2020-2021: Not offered
3-0-9 units

Concepts and physical pictures behind various phenomena that appear in interacting many-body systems. Visualization occurs through concentration on path integral, mean-field theories and semiclassical picture of fluctuations around mean-field state. Topics covered: interacting boson/fermion systems, Fermi liquid theory and bosonization, symmetry breaking and nonlinear sigma-model, quantum gauge theory, quantum Hall theory, mean-field theory of spin liquids and quantum order, string-net condensation and emergence of light and fermions.
X-G. Wen

8.514 Strongly Correlated Systems in Condensed Matter Physics
Prereq: 8.322 and 8.333
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Spring)
3-0-9 units

Study of condensed matter systems where interactions between electrons play an important role. Topics vary depending on lecturer but may include low-dimension magnetic and electronic systems, disorder and quantum transport, magnetic impurities (the Kondo problem), quantum spin systems, the Hubbard model and high-temperature superconductors. Topics are chosen to illustrate the application of diagrammatic techniques, field-theory approaches, and renormalization group methods in condensed matter physics.
S. Todadri

8.581, 8.582 Selected Topics in Condensed Matter Physics
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

Presentation of topics of current interest, with contents varying from year to year. Subject not routinely offered; given when sufficient interest is indicated.

Staff

8.590[J] Topics in Biophysics and Physical Biology
Same subject as 7.74[J], 20.416[J]
Prereq: None
G (Fall)
2-0-4 units
See description under subject 20.416[J].
I. Cisse, N. Fakhri, M. Guo
8.591[J] Systems Biology
Same subject as 7.81[J]
Subject meets with 7.32
Prereq: (18.03 and 18.05) or permission of instructor
G (Fall)
3-0-9 units

Introduction to cellular and population-level systems biology with an emphasis on synthetic biology, modeling of genetic networks, cell-cell interactions, and evolutionary dynamics. Cellular systems include genetic switches and oscillators, network motifs, genetic network evolution, and cellular decision-making. Population-level systems include models of pattern formation, cell-cell communication, and evolutionary systems biology. Students taking graduate version explore the subject in more depth.

J. Gore

8.592[J] Statistical Physics in Biology
Same subject as HST.452[J]
Prereq: 8.333 or permission of instructor
Acad Year 2019-2020: G (Spring)
Acad Year 2020-2021: Not offered
3-0-9 units


M. Kardar, L. Mirny

8.593[J] Biological Physics
Same subject as HST.450[J]
Prereq: 8.044 recommended but not necessary
G (Spring)
Not offered regularly; consult department
4-0-8 units

Designed to provide seniors and first-year graduate students with a quantitative, analytical understanding of selected biological phenomena. Topics include experimental and theoretical basis for the phase boundaries and equation of state of concentrated protein solutions, with application to diseases such as sickle cell anemia and cataract. Protein-ligand binding and linkage and the theory of allosteric regulation of protein function, with application to proteins as stores as transporters in respiration, enzymes in metabolic pathways, membrane receptors, regulators of gene expression, and self-assembling scaffolds. The physics of locomotion and chemoreception in bacteria and the biophysics of vision, including the theory of transparency of the eye, molecular basis of photo reception, and the detection of light as a signal-to-noise discrimination.

G. Benedek

8.613[J] Introduction to Plasma Physics I
Same subject as 22.611[J]
Prereq: (6.013 or 8.07) and (18.04 or Coreq: 18.075)
G (Fall)
3-0-9 units

See description under subject 22.611[J].

I. Hutchinson

8.614[J] Introduction to Plasma Physics II (New)
Same subject as 22.612[J]
Prereq: 22.611[J]
Acad Year 2019-2020: G (Spring)
Acad Year 2020-2021: Not offered
3-0-9 units

See description under subject 22.612[J].

Staff
8.624 Plasma Waves
Prereq: 22.611[J]
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Spring)
3-0-9 units

Comprehensive theory of electromagnetic waves in a magnetized plasma. Wave propagation in cold and hot plasmas. Energy flow. Absorption by Landau and cyclotron damping and by transit time magnetic pumping (TTMP). Wave propagation in inhomogeneous plasma: accessibility, WKB theory, mode conversion, connection formulae, and Budden tunneling. Applications to RF plasma heating, wave propagation in the ionosphere and laser-plasma interactions. Wave propagation in toroidal plasmas, and applications to ion cyclotron (ICRF), electron cyclotron (ECRH), and lower hybrid (LHH) wave heating. Quasi-linear theory and applications to RF current drive in tokamaks. Extensive discussion of relevant experimental observations.

M. Porkolab

8.641 Physics of High-Energy Plasmas I
Prereq: 22.611[J]
G (Fall)
Not offered regularly; consult department
3-0-9 units

Physics of High-Energy Plasmas I and II address basic concepts of plasmas, with temperatures of thermonuclear interest, relevant to fusion research and astrophysics. Microscopic transport processes due to interparticle collisions and collective modes (e.g., microinstabilities). Relevant macroscopic transport coefficients (electrical resistivity, thermal conductivities, particle “diffusion”). Runaway and slide-away regimes. Magnetic reconnection processes and their relevance to experimental observations. Radiation emission from inhomogeneous plasmas. Conditions for thermonuclear burning and ignition (D-T and “advanced” fusion reactions, plasmas with polarized nuclei). Role of “impurity” nuclei. “Finite-β” (pressure) regimes and ballooning modes. Convective modes in configuration and velocity space. Trapped particle regimes. Nonlinear and explosive instabilities. Interaction of positive and negative energy modes. Each subject can be taken independently.

Staff

8.642 Physics of High-Energy Plasmas II
Prereq: 22.611[J]
G (Fall)
Not offered regularly; consult department
3-0-9 units

Physics of High-Energy Plasmas I and II address basic concepts of plasmas, with temperatures of thermonuclear interest, relevant to fusion research and astrophysics. Microscopic transport processes due to interparticle collisions and collective modes (e.g., microinstabilities). Relevant macroscopic transport coefficients (electrical resistivity, thermal conductivities, particle "diffusion"). Runaway and slide-away regimes. Magnetic reconnection processes and their relevance to experimental observations. Radiation emission from inhomogeneous plasmas. Conditions for thermonuclear burning and ignition (D-T and “advanced” fusion reactions, plasmas with polarized nuclei). Role of “impurity” nuclei. “Finite-β” (pressure) regimes and ballooning modes. Convective modes in configuration and velocity space. Trapped particle regimes. Nonlinear and explosive instabilities. Interaction of positive and negative energy modes. Each subject can be taken independently.

M. Porkolab

8.670[J] Principles of Plasma Diagnostics
Same subject as 22.67[J]
Prereq: 22.611[J]
G (Fall)
Not offered regularly; consult department
4-4-4 units

See description under subject 22.67[J].

A. White

8.681, 8.682 Selected Topics in Fluid and Plasma Physics
Prereq: 22.611[J]
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

Presentation of topics of current interest, with content varying from year to year. Subject not routinely offered; given when interest is indicated.

Consult M. Porkolab
**Nuclear and Particle Physics**

**8.701 Introduction to Nuclear and Particle Physics**
Prereq: None. Coreq: 8.321
G (Fall)
3-0-9 units

The phenomenology and experimental foundations of particle and nuclear physics; the fundamental forces and particles, composites. Interactions of particles with matter, and detectors. SU(2), SU(3), models of mesons and baryons. QED, weak interactions, parity violation, lepton-nucleon scattering, and structure functions. QCD, gluon field and color, W and Z fields, electro-weak unification, the CKM matrix. Nucleon-nucleon interactions, properties of nuclei, single- and collective- particle models. Electron and hadron interactions with nuclei. Relativistic heavy ion collisions, and transition to quark-gluon plasma.

*M. Williams*

**8.711 Nuclear Physics**
Prereq: 8.321 and 8.701
G (Spring)
4-0-8 units


*O. Hen*

**8.712 Advanced Topics in Nuclear Physics**
Prereq: 8.711 or permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units

Can be repeated for credit.

Subject for experimentalists and theorists with rotation of the following topics: (1) Nuclear chromodynamics -- introduction to QCD, structure of nucleons, lattice QCD, phases of hadronic matter; and relativistic heavy ion collisions. (2) Medium-energy physics -- nuclear and nucleon structure and dynamics studied with medium- and high-energy probes (neutrinos, photons, electrons, nucleons, pions, and kaons). Studies of weak and strong interactions.

*Staff*

**8.781, 8.782 Selected Topics in Nuclear Theory**
Prereq: 8.323
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units

Presents topics of current interest in nuclear structure and reaction theory, with content varying from year to year. Subject not routinely offered; given when sufficient interest is indicated.

*Consult E. Farhi*

**8.811 Particle Physics**
Prereq: 8.701
G (Fall)
3-0-9 units


*L. Winslow*

**8.812 Graduate Experimental Physics**
Prereq: 8.701
G (IAP)
Not offered regularly; consult department
1-8-3 units

Provides practical experience in particle detection with verification by (Feynman) calculations. Students perform three experiments; at least one requires actual construction following design. Topics include Compton effect, Fermi constant in muon decay, particle identification by time-of-flight, Cerenkov light, calorimeter response, tunnel effect in radioactive decays, angular distribution of cosmic rays, scattering, gamma-gamma nuclear correlations, and modern particle localization.

*U. Becker*
8.821 String Theory  
Prereq: 8.324  
Acad Year 2019-2020: Not offered  
Acad Year 2020-2021: G (Fall)  
3-0-9 units  
Credit cannot also be received for 8.251  
An introduction to string theory. Basics of conformal field theory; light-cone and covariant quantization of the relativistic bosonic string; quantization and spectrum of supersymmetric 10-dimensional string theories; T-duality and D-branes; toroidal compactification and orbifolds; 11-dimensional supergravity and M-theory. Meets with 8.251 when offered concurrently.  
H. Liu

8.831 Supersymmetric Quantum Field Theories  
Prereq: Permission of instructor  
Acad Year 2019-2020: G (Fall)  
Acad Year 2020-2021: Not offered  
3-0-9 units  
Can be repeated for credit.  
Topics selected from the following: SUSY algebras and their particle representations; Weyl and Majorana spinors; Lagrangians of basic four-dimensional SUSY theories, both rigid SUSY and supergravity; supermultiplets of fields and superspace methods; renormalization properties, and the non-renormalization theorem; spontaneous breakdown of SUSY; and phenomenological SUSY theories. Some prior knowledge of Noether’s theorem, derivation and use of Feynman rules, 1-loop renormalization, and gauge theories is essential.  
J. Thaler

8.841 Electroweak Interactions  
Prereq: 8.324  
Acad Year 2019-2020: Not offered  
Acad Year 2020-2021: G (Spring)  
3-0-9 units  
An introduction to the standard model of electroweak interactions and beyond; neutrino interactions and masses; the CKM matrix; lepton scattering off of nucleons and nuclei; the search for the Higgs boson; supersymmetric extension of the standard model. Topics vary with instructor.  
Staff

8.851 Effective Field Theory  
Prereq: 8.324  
Acad Year 2019-2020: G (Spring)  
Acad Year 2020-2021: Not offered  
3-0-9 units  
Credit cannot also be received for 8.851  
Covers the framework and tools of effective field theory, including: identifying degrees of freedom and symmetries; power counting expansions (dimensional and otherwise); field redefinitions, bottom-up and top-down effective theories; fine-tuned effective theories; matching and Wilson coefficients; reparameterization invariance; and advanced renormalization group techniques. Main examples are taken from particle and nuclear physics, including the Soft-Collinear Effective Theory.  
I. Stewart

8.851 Special Subject: Effective Field Theory  
Prereq: 8.324 and permission of instructor  
Acad Year 2019-2020: Not offered  
Acad Year 2020-2021: G (Spring)  
2-0-10 units  
Credit cannot also be received for 8.851  
Experimental version of 8.851, which offers a combination of online and in-person instruction. See description of 8.851. Licensed for Spring 2019 by the Committee on Graduate Programs as an acceptable alternative to 8.851. Limited to 15.  
I. Stewart

8.861 Advanced Topics in Superfluidity  
Prereq: 8.324  
G (Fall)  
Not offered regularly; consult department  
3-0-9 units  
Basic pairing theory, effective field theory and spontaneous symmetry breaking; well-established applications to liquid helium 3 as a warm-up; research will be explored including anisotropic superconductivity in heavy fermion systems and cuprates; color superconductivity in high-density QCD; and pairing in fermion systems with mismatched Fermi surfaces, including ultracold atom systems. Additional ideas needed to discuss the fractional quantum Hall effect will be reviewed, emphasizing its connection to conventional superfluidity, and pointing toward aspects of anyon behavior potentially relevant for quantum information processing.  
Staff
8.871 Selected Topics in Theoretical Particle Physics
Prereq: 8.323
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Fall)
3-0-9 units
Can be repeated for credit.

Presents topics of current interest in theoretical particle physics, with content varying from year to year. Subject not routinely offered; given when sufficient interest is indicated.
F. Wilczek

8.872 Selected Topics in Theoretical Particle Physics
Prereq: 8.323
Acad Year 2019-2020: Not offered
Acad Year 2020-2021: G (Fall, Spring)
3-0-9 units
Can be repeated for credit.

Presents topics of current interest in theoretical particle physics, with content varying from year to year. Subject not routinely offered; given when sufficient interest is indicated.
W. Taylor

8.881, 8.882 Selected Topics in Experimental Particle Physics
Prereq: 8.811
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

Presents topics of current interest in experimental particle physics, with content varying from year to year. Subject not routinely offered; given when sufficient interest is indicated.
Staff

Space Physics and Astrophysics

8.901 Astrophysics I
Prereq: Permission of instructor
G (Spring)
3-0-9 units

S. Hughes

8.902 Astrophysics II
Prereq: 8.901
G (Fall)
3-0-9 units

M. McDonald
**8.913 Plasma Astrophysics I**
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

For students interested in space physics, astrophysics, and plasma physics in general. Magnetospheres of rotating magnetized planets, ordinary stars, neutron stars, and black holes. Pulsar models: processes for slowing down, particle acceleration, and radiation emission; accreting plasmas and x-ray stars; stellar winds; heliosphere and solar wind-relevant magnetic field configuration, measured particle distribution in velocity space and induced collective modes; stability of the current sheet and collisionless processes for magnetic reconnection; theory of collisionless shocks; solitons; Ferroaro-Rosenbluth sheet; solar flare models; heating processes of the solar corona; Earth's magnetosphere (auroral phenomena and their interpretation, bowshock, magnetotail, trapped particle effects); relationship between gravitational (galactic) plasmas and electromagnetic plasmas. 8.913 deals with heliospheric, 8.914 with extra-heliospheric plasmas.

**8.914 Plasma Astrophysics II**
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

For students interested in space physics, astrophysics, and plasma physics in general. Magnetospheres of rotating magnetized planets, ordinary stars, neutron stars, and black holes. Pulsar models: processes for slowing down, particle acceleration, and radiation emission; accreting plasmas and x-ray stars; stellar winds; heliosphere and solar wind-relevant magnetic field configuration, measured particle distribution in velocity space and induced collective modes; stability of the current sheet and collisionless processes for magnetic reconnection; theory of collisionless shocks; solitons; Ferroaro-Rosenbluth sheet; solar flare models; heating processes of the solar corona; Earth's magnetosphere (auroral phenomena and their interpretation, bowshock, magnetotail, trapped particle effects); relationship between gravitational (galactic) plasmas and electromagnetic plasmas. 8.913 deals with heliospheric, 8.914 with extra-heliospheric plasmas.

**8.921 Stellar Structure and Evolution**
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Observable stellar characteristics; overview of observational information. Principles underlying calculations of stellar structure. Physical processes in stellar interiors; properties of matter and radiation; radiative, conductive, and convective heat transport; nuclear energy generation; nucleosynthesis; and neutrino emission. Protostars; the main sequence, and the solar neutrino flux; advanced evolutionary stages; variable stars; planetary nebulae, supernovae, white dwarfs, and neutron stars; close binary systems; and abundance of chemical elements.

**8.942 Cosmology**
Prereq: Permission of instructor
Acad Year 2019-2020: G (Fall)
Acad Year 2020-2021: Not offered
3-0-9 units

Thermal backgrounds in space. Cosmological principle and its consequences: Newtonian cosmology and types of "universes"; survey of relativistic cosmology; horizons. Overview of evolution in cosmology; radiation and element synthesis; physical models of the "early stages." Formation of large-scale structure to variability of physical laws. First and last states. Some knowledge of relativity expected. 8.962 recommended though not required.

**8.952 Particle Physics of the Early Universe**
Prereq: 8.323; Coreq: 8.324
Acad Year 2019-2020: G (Spring)
Acad Year 2020-2021: Not offered
3-0-9 units

Basics of general relativity, standard big bang cosmology, thermodynamics of the early universe, cosmic background radiation, primordial nucleosynthesis, basics of the standard model of particle physics, electroweak and QCD phase transition, basics of group theory, grand unified theories, baryon asymmetry, monopoles, cosmic strings, domain walls, axions, inflationary universe, and structure formation.

A. Guth
8.962 General Relativity
Prereq: 8.07, 18.03, and 18.06
G (Spring)
4-0-8 units
The basic principles of Einstein's general theory of relativity, differential geometry, experimental tests of general relativity, black holes, and cosmology.
A. Guth

8.971 Astrophysics Seminar
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.
Advanced seminar on current topics, with a different focus each term. Typical topics: astronomical instrumentation, numerical and statistical methods in astrophysics, gravitational lenses, neutron stars and pulsars.
Consult D. Chakrabarty

8.972 Astrophysics Seminar
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.
Advanced seminar on current topics, with a different focus each term. Typical topics: gravitational lenses, active galactic nuclei, neutron stars and pulsars, galaxy formation, supernovae and supernova remnants, brown dwarfs, and extrasolar planetary systems. The presenter at each session is selected by drawing names from a hat containing those of all attendees. Offered if sufficient interest is indicated.
Consult D. Chakrabarty

8.981, 8.982 Selected Topics in Astrophysics
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.
Topics of current interest, varying from year to year. Subject not routinely offered; given when sufficient interest is indicated.
Consult D. Chakrabarty

8.995 Practical Work Experience
Prereq: None
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.
For Course 8 students participating in off-campus work experiences in physics. Before registering for this subject, students must have an employment offer from a company or organization, must identify a Physics supervisor, and must receive prior approval from the Physics Department. Upon completion of the work, student must submit a letter from the employer describing the work accomplished, along with a substantive final report from the student approved by the MIT supervisor. Consult departmental academic office.
Consult N. Mavalvala

8.5301 Special Subject: Physics
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
Units arranged
Covers topics in Physics that are not offered in the regular curriculum. Limited enrollment; preference to Physics graduate students.
A. Lightman

8.5421 Special Subject: Physics
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.
Opportunity for group study of subjects in physics not otherwise included in the curriculum.
W. Ketterle

8.THG Graduate Physics 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 an appropriate MIT faculty member.
Consult I. Stewart