# DEPARTMENT OF PHYSICS

The Department of Physics offers undergraduate, graduate, and postgraduate training, with a wide range of options for specialization.

The emphasis of both the undergraduate curriculum and the graduate program is on understanding the fundamental principles that appear to govern the behavior of the physical world, including space and time and matter and energy in all its forms, from the subatomic to the cosmological and from the elementary to the complex.

The Department of Physics strives to be at the forefront of many areas where new physics can be found. Consequently, the department works on problems where extreme conditions may reveal new behavior: from clusters of galaxies or the entire universe to elementary particles or the strings that may be the substructure of these particles; from collisions of nuclei at relativistic velocities that make droplets of matter hotter than anything since the Big Bang to laser-cooled atoms so cold that their wave functions overlap, resulting in a macroscopic collective state, the Bose-Einstein condensate; and from individual atoms to unusual materials, such as high-temperature superconductors and those that are important in biology. Pushing the limits provides the opportunity to observe new general principles and test theories of the structure and behavior of matter and energy.

## Undergraduate Study

### *Bachelor of Science in Physics (Course 8)*

An undergraduate degree in physics provides an excellent basis not only for graduate study in physics and related fields, but also for professional work in such fields as astrophysics, biophysics, engineering and applied physics, geophysics, management, law, or medicine. The undergraduate curriculum offers students the opportunity to acquire a deep conceptual understanding of fundamental physics. The core departmental requirements begin this process. The student then chooses one of two options to complete the degree: the focused option (*http://catalog.mit.edu/degree-charts/physics-course-8/#focusedoptiontext*) is designed for students who plan to pursue physics as a career, and is an excellent choice for students who want to experience as deep an engagement as possible with physics; the flexible option (*http://catalog.mit.edu/degree-charts/physics-course-8/#flexibleoptiontext*) also provides a very strong physics framework, and gives students who may want to pursue additional academic interests the flexibility to do so. Both programs prepare students very well for graduate studies in physics, as well as for a variety of academic or research-related careers. Either option provides a considerable amount of time for exploration through electives. Students proceed at the pace and degree of specialization best suited to their individual capacities. Both options lead to the same degree: the Bachelor of Science in Physics.

#### Physics: Focused Option

This option—which includes three terms of quantum mechanics, 36 units of laboratory experience, and a thesis—is ideal preparation for a career in physics.

In the second year, students take:

| | | |
|---|---|---|
| 8.03 | Physics III | 12 |
| 8.033 | Relativity | 12 |
| 8.04 | Quantum Physics I | 12 |
| 8.044 | Statistical Physics I | 12 |
| 8.223 | Classical Mechanics II | 6 |

Important skills for experimentation in physics may be acquired by starting an Undergraduate Research Opportunities Program (UROP) (*http://catalog.mit.edu/mit/undergraduate-education/academic-research-options/undergraduate-research-opportunities-program*) project.

In the third year, students normally take laboratory subjects:

| | | |
|---|---|---|
| 8.13<br>& 8.14 | Experimental Physics I<br>and Experimental Physics II | 36 |
| 8.05<br>& 8.06 | Quantum Physics II<br>and Quantum Physics III | 24 |

Students should also begin to take the restricted elective subjects, one in mathematics and at least two in physics. The mathematics subjects 18.04 Complex Variables with Applications, 18.075 Methods for Scientists and Engineers, and 18.06 Linear Algebra are particularly popular with physics majors. Topical elective subjects in astrophysics, biological physics, condensed matter, plasma, and nuclear and particle physics allow students to gain an appreciation of the forefronts of modern physics. Students intending to go on to graduate school in physics are encouraged to take the theoretical physics sequence:

| | | |
|---|---|---|
| 8.07 | Electromagnetism II | 12 |
| 8.08 | Statistical Physics II | 12 |
| 8.09 | Classical Mechanics III | 12 |

An important component of this option is the thesis, which is a physics research project carried out under the guidance of a faculty member. Many thesis projects grow naturally out of UROP projects. Students should have some idea of a thesis topic by the middle of the junior year. A thesis proposal must be submitted before registering for thesis units and no later than Add Date of the fall term of the senior year.

A relatively large amount of elective time usually becomes available during the fourth year and can be used either to deepen one's background in physics or to explore other disciplines.

**Physics: Flexible Option**

This option is designed for students who wish to develop a strong background in the fundamentals of physics and then build on this foundation as they prepare for career paths that may or may not involve a graduate degree in physics. Many students find an understanding of the basic concepts of physics and an appreciation of the physicist's approach to problem solving an excellent preparation for the growing spectrum of nontraditional, technology-related career opportunities, as well as for careers in business, law, medicine, or engineering. Additionally, the flexible option makes it more possible for students with diverse intellectual interests to pursue a second major in another department.

The option begins with the core subjects:

| | | |
|---|---|---|
| 8.01 | Physics I | 12 |
| 8.02 | Physics II | 12 |
| 8.03 | Physics III | 12 |
| 8.04 | Quantum Physics I | 12 |
| 8.044 | Statistical Physics I | 12 |
| 8.21 | Physics of Energy | 12 |
| or 8.223 | Classical Mechanics II | |

Students round out their foundation material with either an additional quantum mechanics subject (8.05 Quantum Physics II) or a subject in relativity (8.20 Introduction to Special Relativity or 8.033 Relativity). There is an experimental requirement of 8.13 Experimental Physics I or, with the approval of the department, a laboratory subject of similar intensity in another department, an experimental research project or senior thesis, or an experimentally oriented summer externship. An exploration requirement consists of one elective subject in physics. Students can satisfy the departmental portion of the Communication Requirement by taking two of the following subjects:

| | | |
|---|---|---|
| 8.06 | Quantum Physics III | 12 |
| 8.13 | Experimental Physics I | 18 |
| 8.14 | Experimental Physics II | 18 |
| 8.225[J] | Einstein, Oppenheimer, Feynman: Physics in the 20th Century | 12 |
| 8.226 | Forty-three Orders of Magnitude | 12 |
| 8.287[J] | Observational Techniques of Optical Astronomy | 15 |

The department and the Subcommittee on the Communication Requirement may accept substitution of one of the department's two required CI-M subjects with a CI-M subject in another department if it forms a natural part of the student's physics program.

Students following this option must also complete a focus requirement—three subjects forming one intellectually coherent unit in some area (not necessarily physics), subject to the approval of the department and separate from those used by the student to satisfy the HASS requirement. Areas of focus chosen by students have included astronomy, biology, computational physics, theoretical physics, nanotechnology, history of science, science and technology policy, philosophy, and science teaching. Some students may choose to satisfy their experimental and exploration requirements in the same area as their focus; others may opt for greater breadth by choosing other fields to fulfill these requirements.

Although students may choose this option at any time in their undergraduate career, many decide on the flexible major during their sophomore year in order to have enough time to craft a program that best suits their individual needs. Specific subject choices for the experimental and focus requirements require the written approval of the Flexible Program coordinator, Dr. Sean P. Robinson.

***Minor in Physics***

The Minor in Physics provides a solid foundation for the pursuit of a broad range of professional activities in science and engineering. The requirements for a Minor in Physics are as follows:

| | | |
|---|---|---|
| 18.03 | Differential Equations [1] | 12 |
| Select five Course 8 subjects beyond the General Institute Requirements | | 57-60 |
| **Total Units** | | **69-72** |

[1] *18.032 Differential Equations is also acceptable.*

Students should submit a completed Minor Application Form to Physics Academic Programs, Room 4-315. The Physics Department's minor coordinator is Catherine Modica. See Undergraduate Education for more information on minor programs (*http://catalog.mit.edu/mit/undergraduate-education/academic-programs/minors*).

***Minor in Astronomy***

The Minor in Astronomy (*http://catalog.mit.edu/interdisciplinary/undergraduate-programs/minors/astronomy*), offered jointly with the Department of Earth, Atmospheric, and Planetary Sciences, covers the observational and theoretical foundations of astronomy. For a description of the minor, see Interdisciplinary Programs.

***Inquiries***

Additional information concerning degree programs and research activities may be obtained by contacting the department office (*physics-undergrad@mit.edu*), Room 4-315, 617-253-4841.

## Graduate Study

The Physics Department offers programs leading to the degrees of Master of Science in Physics and Doctor of Philosophy.

### *Admission Requirements for Graduate Study*

Students intending to pursue graduate work in physics should have as a background the equivalent of the requirements for the Bachelor of Science in Physics from MIT. However, students may make up some deficiencies over the course of their graduate work.

### *Master of Science in Physics*

The normal degree program in the department leads to a PhD in Physics. Admission to a master's degree program in Physics is available only in special cases (e.g., US military officers). The requirements for the Master of Science in Physics are the same as the General Degree Requirements (*http://catalog.mit.edu/mit/graduate-education/general-degree-requirements*) listed under Graduate Education. A master's thesis must represent a piece of independent research work in any of the fields described below, and must be carried out under the supervision of a department faculty member. No fixed time is set for the completion of a master's program; two years of work is a rough guideline. There is no language requirement for this degree.

### *Doctor of Philosophy*

Candidates for the Doctor of Philosophy or Doctor of Science are expected to enroll in those basic graduate subjects that prepare them for the general examination, which must be passed no later than in the seventh term after initial enrollment. Students are required to take two subjects in the candidate's doctoral research area (specialty requirement) and two subjects outside the candidate's field of specialization (breadth requirement). In addition, all students in the first year of the PhD program must enroll in two semesters of 8.398, a seminar specifically for first-year students. Half of the breadth requirement may be satisfied through a departmentally approved industrial internship. The doctoral thesis must represent a substantial piece of original research, carried out under the supervision of a department faculty member.

The Physics Department faculty members offer subjects of instruction and are engaged in research in a variety of fields in experimental and theoretical physics. This broad spectrum of activities is organized in the divisional structure of the department, presented below. Graduate students are encouraged to contact faculty members in the division of their choice to inquire about opportunities for research, and to pass through an apprenticeship (by signing up for Pre-Thesis Research) as a first step toward an engagement in independent research for a doctoral thesis.

### *Research Divisions*

Faculty and students in the Department of Physics are generally affiliated with one of several research divisions:

- Astrophysics
- Experimental Nuclear and Particle Physics
- Atomic Physics, Biophysics, Condensed Matter Physics, and Plasma Physics
- Theoretical Nuclear and Particle Physics

Much of the research in the department is carried out as part of the work of various interdisciplinary laboratories and centers, including the Center for Materials Science and Engineering, Francis Bitter Magnet Laboratory, Haystack Observatory, Laboratory for Nuclear Science, Microsystems Technology Laboratories, MIT Kavli Institute for Astrophysics and Space Research, Plasma Science and Fusion Center, Research Laboratory of Electronics, and Spectroscopy Laboratory. Additional information about interdisciplinary laboratories and centers can be found under Research and Study (*http://catalog.mit.edu/mit/research*). These facilities provide close relationships among the research activities of a number of MIT departments and give students opportunities for contact with research carried out in disciplines other than physics.

### *Inquiries*

Additional information on degree programs, research activities, admissions, financial aid, teaching and research assistantships may be obtained by contacting the department office (*physics-grad@mit.edu*), Room 4-315, 617-253-4851.

## Faculty and Teaching Staff

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Professor of Physics
Head, Department of Physics

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Professor of Physics
Associate Head, Department of Physics

### *Professors*

Raymond Ashoori, PhD
Professor of Physics

Edmund Bertschinger, PhD
Professor of Physics

Claude R. Canizares, PhD
Bruno B. Rossi Distinguished Professor in Experimental Physics

Paola Cappellaro, PhD
Ford Professor of Engineering
Professor of Nuclear Science and Engineering
Professor of Physics

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Professor of Chemistry
Professor of Physics
Core Faculty, Institute for Medical Engineering and Science

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Professor of Physics

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Professor of Physics

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Professor of Physics

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Professor of Physics

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Associate Provost and Associate Vice President for Research

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Professor Post-Tenure of Physics

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Dean, School of Science

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Senthil Todadri, PhD
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Lester Wolfe Professor
Professor of Physics

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Thomas A. Frank (1977) Professor of Physics

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## Research Staff

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## Professors Emeriti

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Professor Emeritus of Biological Physics

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Hale V. Bradt, PhD
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Professor Emeritus of Physics

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Rainer Weiss, PhD
Professor Emeritus of Physics

James E. Young, PhD
Professor Emeritus of Physics

## 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, ES.8012

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: Permission of instructor
U (Spring)
5-0-7 units. PHYSICS I
Credit cannot also be received for 8.01, 8.012, 8.01L, ES.801, ES.8012

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.
*B. Drury*

**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, ES.8012

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, ES.8012

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 Schwarzchild 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 8.041

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*

**8.041 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

Blended version of 8.04 using a combination of online and in-person instruction. Covers 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*

**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 or 8.041
U (Fall)
5-0-7 units
Credit cannot also be received for 8.051

Vector spaces, linear operators, and matrix representations.  Inner products and adjoint operators. Commutator identities. Dirac's Bra-kets. Uncertainty principle and energy-time version. Spectral theorem and complete set of commuting observables. Schrodinger and Heisenberg pictures.  Axioms of quantum mechanics. Coherent states and nuclear magnetic resonance. Multiparticle states and tensor products. Quantum teleportation, EPR and Bell inequalities. Angular momentum and central potentials. Addition of angular momentum. Density matrices, pure and mixed states, decoherence.
*B. Zwiebach*

**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

Blended version of 8.05 using a combination of online and in-person instruction. Together with 8.06 covers quantum physics with applications drawn from modern physics. General formalism of quantum mechanics: states, operators, Dirac notation, representations, measurement theory. Harmonic oscillator: operator algebra, states. Quantum mechanics in three dimensions: central potentials and the radial equation, bound and scattering states, qualitative analysis of wave functions. Angular momentum: operators, commutator algebra, eigenvalues and eigenstates, spherical harmonics. Spin: Stern-Gerlach devices and measurements, nuclear magnetic resonance, spin and statistics. Addition of angular momentum: Clebsch-Gordan series and coefficients, spin systems, and allotropic forms of hydrogen. Limited to 20.
*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

Survey of basic electromagnetic phenomena: electrostatics, magnetostatics; electromagnetic properties of matter. Time-dependent electromagnetic fields and Maxwell's equations. Electromagnetic waves, emission, absorption, and scattering of radiation. Relativistic electrodynamics and mechanics.
*A. Guth*

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

Probability distributions for classical and quantum systems. Microcanonical, canonical, and grand canonical partition-functions and associated thermodynamic potentials. Conditions of thermodynamic equilibrium for homogenous and heterogenous systems. Applications: non-interacting Bose and Fermi gases; mean field theories for real gases, binary mixtures, magnetic systems, polymer solutions; phase and reaction equilibria, critical phenomena. Fluctuations, correlation functions and susceptibilities, and Kubo formulae. Evolution of distribution functions: Boltzmann and Smoluchowski equations.
*Staff, L. Fu*

**8.09 Classical Mechanics III**
Subject meets with 8.309
Prereq: 8.223
U (Fall, Spring)
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

**8.10 Exploring and Communicating Physics (and other) Frontiers**
Prereq: None
U (Fall)
Not offered regularly; consult department
2-0-0 units

Features a series of 12 interactive sessions that span a wide variety of topics at the frontiers of science - e.g., quantum computing, dark matter, the nature of time - and encourage independent thinking. Discussions draw from the professor's published pieces in periodicals as well as short excerpts from his books. Also discusses, through case studies, the process of writing and re-writing. Subject can count toward the 6-unit discovery-focused credit limit for first year students.
*F. Wilczek*

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

First in a two-term advanced laboratory sequence in modern physics focusing on the professional and personal development of the student as a scientist through the medium of experimental physics. Experimental options cover special relativity, experimental foundations of quantum mechanics, atomic structure and optics, statistical mechanics, and nuclear and particle physics. Uses modern physics experiments to develop laboratory technique, systematic troubleshooting, professional scientific attitude, data analysis skills and reasoning about uncertainty. Provides extensive training in oral and written communication methods. Limited to 12 students per section.
*J. Conrad, N. Fakhri, C. Paus, G. Roland*

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

Second in a two-term advanced laboratory sequence in modern physics focusing on the professional and personal development of the student as a scientist through the medium of experimental physics. Experimental options cover special relativity, experimental foundations of quantum mechanics, atomic structure and optics, statistical mechanics, and nuclear and particle physics. Uses modern physics experiments to develop laboratory technique, systematic troubleshooting, professional scientific attitude, data analysis skills, and reasoning about uncertainty; provides extensive training in oral and written communication methods. Continues 8.13 practice in these skills using more advanced experiments and adds an exploratory project element in which students develop an experiment from the proposal and design stage to a final presentation of results in a poster session. Limited to 12 students per section.
*G. Roland*

**8.16 Data Science in Physics**
Subject meets with 8.316
Prereq: 8.04 and (6.100A, 6.100B, or permission of instructor)
U (Spring)
3-0-9 units

Aims to present modern computational methods by providing realistic, contemporary examples of how these computational methods apply to physics research. Designed around research modules in which each module provides experience with a specific scientific challenge. Modules include: analyzing LIGO open data; measuring electroweak boson to quark decays; understanding the cosmic microwave background; and lattice QCD/Ising model. Experience in Python helpful but not required. Lectures are viewed outside of class; in-class time is dedicated to problem-solving and discussion. Students taking graduate version complete additional assignments.
*P. Harris*

**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
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: U (Fall)
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 2023-2024: U (Spring)
Acad Year 2024-2025: Not offered
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 2023-2024: U (Spring)
Acad Year 2024-2025: Not offered
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*

**8.228 Relativity II**
Prereq: 8.033 or permission of instructor
U (IAP)
2-0-4 units

A fast-paced and intensive introduction to general relativity, covering advanced topics beyond the 8.033 curriculum. Provides students with a foundation for research relying on knowledge of general relativity, including gravitational waves and cosmology. Additional topics in curvature, weak gravity, and cosmology.
*T. Slatyer*

**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**
Prereq: Physics II (GIR) and (8.044 or (5.601 and 5.602))
Acad Year 2023-2024: U (Spring)
Acad Year 2024-2025: Not offered
4-0-8 units
Credit cannot also be received for 20.315, 20.415

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. Meets with 20.315 and 20.415 when offered concurrently.
*J. Gore*

**8.245[J] Viruses, Pandemics, and Immunity**
Same subject as 5.003[J], 10.382[J], HST.439[J]
Subject meets with 5.002[J], 10.380[J], HST.438[J]
Prereq: None
U (Spring)
Not offered regularly; consult department
2-0-1 units

See description under subject HST.439[J]. HST.438[J] intended for first-year students; all others should take HST.439[J].
*A. Chakraborty*

**8.251 String Theory for Undergraduates**
Prereq: 8.033, 8.044, and 8.05
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: 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: (6.2300 or 8.07) and permission of instructor
U (Fall, IAP, Spring)
Not offered regularly; consult department
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 the physics of planets, stars, galaxies and our universe, from origin to ultimate fate, with emphasis on the physics tools and observational techniques that enable our understanding. Topics include our solar system, extrasolar planets; our Sun and other "normal" stars, star formation, evolution and death, supernovae, compact objects (white dwarfs, neutron stars, pulsars, stellar-mass black holes); galactic structure, star clusters, interstellar medium, dark matter; other galaxies, quasars, supermassive black holes, gravitational waves; cosmic large-scale structure, origin, evolution and fate of our universe, inflation, dark energy, cosmic microwave background radiation, gravitational lensing, 21cm tomography. Not usable as a restricted elective by Physics majors.
*M. Tegmark*

**8.284 Modern Astrophysics**
Prereq: 8.04; *Coreq: 8.05*
U (Fall)
3-0-9 units

Application of physics (Newtonian, statistical, and quantum mechanics; special and general relativity) to fundamental processes that occur in celestial objects. Includes main-sequence stars, collapsed stars (white dwarfs, neutron stars, and black holes), pulsars, galaxies, active galaxies, quasars, and cosmology. Electromagnetic and gravitational radiation signatures of astrophysical phenomena explored through examination of observational data. No prior knowledge of astronomy required.
*J. Hewitt*

**8.286 The Early Universe**
Prereq: Physics II (GIR) and 18.03
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: 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.
*M. Person, R. Teague*

**8.290[J] Extrasolar Planets: Physics and Detection Techniques**
Same subject as 12.425[J]
Subject meets with 12.625
Prereq: 8.03 and 18.03
U (Fall)
3-0-9 units. REST

See description under subject 12.425[J].
*S. Seager*

**8.292[J] Fluid Physics**
Same subject as 1.066[J], 12.330[J]
Prereq: 5.60, 8.044, or permission of instructor
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: U (Spring)
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.
*L. Bourouiba*

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

For Course 8 students participating in off-campus experiences in physics. Before registering for this subject, students must have an internship offer from a company or organization and must identify a Physics supervisor. Upon completion of the project, student must submit a letter from the company or organization 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: None
U (Fall, Spring)
0-0-1 units
Can be repeated for credit.

See description under subject 2.EPE. Application required; consult UPOP website for more information.
*K. Tan-Tiongco, D. Fordell*

**8.S02 Special Subject: Physics**
Prereq: None
U (Spring)
Not offered regularly; consult department
1-0-2 units

Opportunity for group study of subjects in physics not otherwise included in the curriculum.
*P. Dourmashkin*

**8.S227 Special Subject: Physics**
Prereq: None
U (Fall)
Not offered regularly; consult department
3-0-9 units

Opportunity for group study of subjects in physics not otherwise included in the curriculum.
*R. Price*

**8.S228 Special Subject: Physics**
Prereq: None
U (IAP)
Not offered regularly; consult department
2-0-4 units

Opportunity for group study of subjects in physics not otherwise included in the curriculum.
*T. Slatyer*

**8.S271 Special Subject: Physics**
Prereq: None
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: U (Spring)
2-0-4 units

Opportunity for group study of subjects in physics not otherwise included in the curriculum.
*R. Redwine*

**8.S30 Special Subject: Physics**
Prereq: None
Acad Year 2023-2024: U (Fall, Spring)
Acad Year 2024-2025: Not offered
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)
Not offered regularly; consult department
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, Spring)
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*

**8.315[J] Mathematical Methods in Nanophotonics**
Same subject as 18.369[J]
Prereq: 8.07, 18.303, or permission of instructor
Acad Year 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
3-0-9 units

See description under subject 18.369[J].
*S. G. Johnson*

**8.316 Data Science in Physics**
Subject meets with 8.16
Prereq: 8.04 and (6.100A, 6.100B, or permission of instructor)
Acad Year 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
3-0-9 units

Aims to present modern computational methods by providing realistic, contemporary examples of how these computational methods apply to physics research. Designed around research modules in which each module provides experience with a specific scientific challenge. Modules include: analyzing LIGO open data; measuring electroweak boson to quark decays; understanding the cosmic microwave background; and lattice QCD/Ising model. Experience in Python helpful but not required. Lectures are viewed outside of class; in-class time is dedicated to problem-solving and discussion. Students taking graduate version complete additional assignments.
*P. Harris*

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

A two-term subject on quantum theory, stressing principles: uncertainty relation, observables, eigenstates, eigenvalues, probabilities of the results of measurement, transformation theory, equations of motion, and constants of motion. Symmetry in quantum mechanics, representations of symmetry groups. Variational and perturbation approximations. Systems of identical particles and applications. Time-dependent perturbation theory. Scattering theory: phase shifts, Born approximation. The quantum theory of radiation. Second quantization and many-body theory. Relativistic quantum mechanics of one electron.
*H. Liu*

**8.322 Quantum Theory II**
Prereq: 8.07 and 8.321
Acad Year 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
4-0-8 units

A two-term subject on quantum theory, stressing principles: uncertainty relation, observables, eigenstates, eigenvalues, probabilities of the results of measurement, transformation theory, equations of motion, and constants of motion. Symmetry in quantum mechanics, representations of symmetry groups. Variational and perturbation approximations. Systems of identical particles and applications. Time-dependent perturbation theory. Scattering theory: phase shifts, Born approximation. The quantum theory of radiation. Second quantization and many-body theory. Relativistic quantum mechanics of one electron.
*S. Todadri*

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

A one-term self-contained subject in quantum field theory. Concepts and basic techniques are developed through applications in elementary particle physics, and condensed matter physics. Topics: classical field theory, symmetries, and Noether's theorem. Quantization of scalar fields, spin fields, and Gauge bosons. Feynman graphs, analytic properties of amplitudes and unitarity of the S-matrix. Calculations in quantum electrodynamics (QED). Introduction to renormalization.
*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 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
4-0-8 units

Second part of a two-subject sequence on statistical mechanics. Explores topics from modern statistical mechanics: the hydrodynamic limit and classical field theories. Phase transitions and broken symmetries: universality, correlation functions, and scaling theory. The renormalization approach to collective phenomena. Dynamic critical behavior. Random systems.
*Staff*

**8.351[J] Classical Mechanics: A Computational Approach**
Same subject as 6.5160[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*

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

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

**8.371[J] Quantum Information Science**
Same subject as 6.6420[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*

**8.372 Quantum Information Science III**
Prereq: 8.371[J]
Acad Year 2023-2024: G (Fall)
Acad Year 2024-2025: Not offered
3-0-9 units

Third subject in the Quantum Information Science (QIS) sequence, building on 8.370[J] and 8.371[J]. Further explores core topics in quantum information science, such as quantum information theory, error-correction, physical implementations, algorithms, cryptography, and complexity. Draws connections between QIS and related fields, such as many-body physics, and applications such as sensing.
*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
G (Fall)
2-0-2 units

See description under subject 5.95[J].
*J. Rankin*

**8.396[J] Leadership and Professional Strategies & Skills Training (LEAPS), Part I: Advancing Your Professional Strategies and Skills**
Same subject as 5.961[J], 9.980[J], 12.396[J], 18.896[J]
Prereq: None
G (Spring; second half of term)
2-0-1 units

Part I (of two parts) of the LEAPS graduate career development and training series. Topics include: navigating and charting an academic career with confidence; convincing an audience with clear writing and arguments; mastering public speaking and communications; networking at conferences and building a brand; identifying transferable skills; preparing for a successful job application package and job interviews; understanding group dynamics and different leadership styles; leading a group or team with purpose and confidence. Postdocs encouraged to attend as non-registered participants. Limited to 80.
*A. Frebel*

**8.397[J] Leadership and Professional Strategies & Skills Training (LEAPS), Part II: Developing Your Leadership Competencies**
Same subject as 5.962[J], 9.981[J], 12.397[J], 18.897[J]
Prereq: None
G (Spring; first half of term)
2-0-1 units

Part II (of two parts) of the LEAPS graduate career development and training series. Topics covered include gaining self awareness and awareness of others, and communicating with different personality types; learning about team building practices; strategies for recognizing and resolving conflict and bias; advocating for diversity and inclusion; becoming organizationally savvy; having the courage to be an ethical leader; coaching, mentoring, and developing others; championing, accepting, and implementing change. Postdocs encouraged to attend as non-registered participants. Limited to 80.
*D. Rigos*

**8.398 Selected Topics in Graduate Physics**
Prereq: None
G (Fall, Spring)
Units arranged
Can be repeated for credit.

A seminar for first-year PhD students presenting topics of current interest, with content varying from year to year. Open only to first-year graduate students in Physics.
*Consult J. Thaler*

**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 2023-2024: G (Spring)
Acad Year 2024-2025: 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 phsyics. 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 2023-2024: Not offered
Acad Year 2024-2025: 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 6.6340[J]
Prereq: 6.2300 or 8.03
G (Spring)
3-0-9 units

See description under subject 6.6340[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

First term of a theoretical treatment of the physics of solids. Concept of elementary excitations. Symmetry- translational, rotational, and time-reversal invariances- theory of representations. Energy bands- electrons and phonons. Topological band theory. Survey of electronic structure of metals, semimetals, semiconductors, and insulators, excitons, critical points, response functions, and interactions in the electron gas. Theory of superconductivity.
*L. Levitov*

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

Second term of a theoretical treatment of the physics of solids. Interacting electron gas: many-body formulation, Feynman diagrams, random phase approximation and beyond. General theory of linear response: dielectric function; sum rules; plasmons; optical properties; applications to semiconductors, metals, and insulators. Transport properties: non-interacting electron gas with impurities, diffusons. Quantum Hall effect: integral and fractional. Electron-phonon interaction: general theory, applications to metals, semiconductors and insulators, polarons, and field-theory description. Superconductivity: experimental observations, phenomenological theories, and BCS theory.
*L. Levitov*

**8.513 Many-Body Theory for Condensed Matter Systems**
Prereq: 8.033, 8.05, 8.08, and 8.231
Acad Year 2023-2024: G (Fall)
Acad Year 2024-2025: 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 2023-2024: Not offered
Acad Year 2024-2025: 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
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
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
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Fall)
2-0-4 units

Provides broad exposure to research in biophysics and physical biology, with emphasis on the critical evaluation of scientific literature. Weekly meetings include in-depth discussion of scientific literature led by distinct faculty on active research topics. Each session also includes brief discussion of non-research topics including effective presentation skills, writing papers and fellowship proposals, choosing scientific and technical research topics, time management, and scientific ethics.
*J. Gore, N. Fakhri*

**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 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
3-0-9 units

A survey of problems at the interface of statistical physics and modern biology: bioinformatic methods for extracting information content of DNA; gene finding, sequence comparison, phylogenetic trees. Physical interactions responsible for structure of biopolymers; DNA double helix, secondary structure of RNA, elements of protein folding. Considerations of force, motion, and packaging; protein motors, membranes. Collective behavior of biological elements; cellular networks, neural networks, and evolution.
*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: (6.2300 or 8.07) and (18.04 or *Coreq: 18.075*)
G (Fall)
3-0-9 units

See description under subject 22.611[J].
*N. Loureiro, I. Hutchinson*

**8.614[J] Introduction to Plasma Physics II**
Same subject as 22.612[J]
Prereq: 22.611[J]
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
3-0-9 units

See description under subject 22.612[J].
*N. Loureiro*

**8.624 Plasma Waves**
Prereq: 22.611[J]
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: 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-$\beta$" (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-$\beta$" (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*

**8.670[J] Principles of Plasma Diagnostics**
Same subject as 22.67[J]
Prereq: 22.611[J]
Acad Year 2023-2024: G (Fall)
Acad Year 2024-2025: Not offered
4-4-4 units

See description under subject 22.67[J].
*J. Hare, 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

Modern, advanced study in the experimental foundations and theoretical understanding of the structure of nuclei, beginning with the two- and three-nucleon problems. Basic nuclear properties, collective and single-particle motion, giant resonances, mean field models, interacting boson model. Nuclei far from stability, nuclear astrophysics, big-bang and stellar nucleosynthesis. Electron scattering: nucleon momentum distributions, scaling, olarization observables. Parity-violating electron scattering. Neutrino physics. Current results in relativistic heavy ion physics and hadronic physics. Frontiers and future facilities.
*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*

**8.751[J] Quantum Technology and Devices**
Same subject as 22.51[J]
Subject meets with 22.022
Prereq: 22.11
G (Spring)
3-0-9 units

See description under subject 22.51[J].
*P. Cappellaro*

**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

Modern review of particles, interactions, and recent experiments. Experimental and analytical methods. QED, electroweak theory, and the Standard Model as tested in recent key experiments at ee and pp colliders. Mass generation, W, Z, and Higgs physics. Weak decays of mesons, including heavy flavors with QCD corrections. Mixing phenomena for K, D, B mesons and neutrinos. CP violation with results from B-factories. Future physics expectations: Higgs, SUSY, sub-structure as addressed by new experiments at the LHC collider.
*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 2023-2024: Not offered
Acad Year 2024-2025: 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 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
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, l-loop renormalization, and gauge theories is essential.
*J. Thaler*

**8.851 Effective Field Theory**
Prereq: 8.324
Acad Year 2023-2024: G (Spring)
Acad Year 2024-2025: Not offered
3-0-9 units
Credit cannot also be received for 8.S851

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*

**8.871 Selected Topics in Theoretical Particle Physics**
Prereq: 8.323
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: 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 2023-2024: Not offered
Acad Year 2024-2025: 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

Size and time scales. Historical astronomy. Astronomical instrumentation. Stars: spectra and classification. Stellar structure equations and survey of stellar evolution. Stellar oscillations. Degenerate and collapsed stars; radio pulsars. Interacting binary systems; accretion disks, x-ray sources. Gravitational lenses; dark matter. Interstellar medium: HII regions, supernova remnants, molecular clouds, dust; radiative transfer; Jeans' mass; star formation. High-energy astrophysics: Compton scattering, bremsstrahlung, synchrotron radiation, cosmic rays. Galactic stellar distributions and populations; Oort constants; Oort limit; and globular clusters.
*S. Hughes*

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

Galactic dynamics: potential theory, orbits, collisionless Boltzmann equation, etc. Galaxy interactions. Groups and clusters; dark matter. Intergalactic medium; x-ray clusters. Active galactic nuclei: unified models, black hole accretion, radio and optical jets, etc. Homogeneity and isotropy, redshift, galaxy distance ladder. Newtonian cosmology. Roberston-Walker models and cosmography. Early universe, primordial nucleosynthesis, recombination. Cosmic microwave background radiation. Large-scale structure, galaxy formation.
*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.
*Staff*

**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.
*B. Coppi*

**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.
*Staff*

**8.942 Cosmology**
Prereq: Permission of instructor
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Fall)
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.
*K. Masui*

**8.952 Particle Physics of the Early Universe**
Prereq: 8.323; *Coreq: 8.324*
Acad Year 2023-2024: Not offered
Acad Year 2024-2025: G (Spring)
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 Experience in Physics**
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 experiences in physics. Before registering for this subject, students must have an internship offer from a company or organization, must identify a Physics supervisor, and must receive prior approval from the Physics Department. Upon completion of the project, student must submit a letter from the company or organization 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*

**8.998 Teaching and Mentoring MIT Students (New)**
Prereq: None
U (Fall, Spring)
2-0-1 units

Designed for first-time physics mentors and others interested in improving their knowledge and skills in teaching one-on-one and in small groups, particularly TEAL TAs and graduate student TAs. Topics include: cognition, metacognition, and the role of affect; communication skills (practice listening, questioning, and eliciting student ideas); the roles of motivation and mindset in learning; fostering belonging and self-efficacy through peer mentorship; facilitating small-group interactions to enhance peer instruction and learning; physics-specific learning strategies, such as how to teach/learn problem solving; research-based techniques for effective mentorship in STEM. Includes a one-hour class on pedagogy topics, a one-hour weekly Physics Mentoring Community of Practice meeting, and weekly assignments to read or watch material in preparation for class discussions, and written reflections before class.
*E. Bertschinger*

**8.S301 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.S372 Special Subject: Physics**
Prereq: None
G (Spring)
3-0-9 units

Covers topics in Physics that are not offered in the regular curriculum.
*A. Harrow*

**8.S396 Special Subject: Physics**
Prereq: None
G (Spring; first half of term)
Not offered regularly; consult department
Units arranged [P/D/F]

Covers topics in Physics that are not offered in the regular curriculum.
*A. Frebel*

**8.S397 Special Subject: Physics**
Prereq: None
G (Spring; second half of term)
Not offered regularly; consult department
Units arranged [P/D/F]

Covers topics in Physics that are not offered in the regular curriculum.
*A. Frebel*

**8.S421 Special Subject: Physics**
Prereq: Permission of instructor
G (IAP)
Units arranged
Can be repeated for credit.

Opportunity for group study of subjects in physics not otherwise included in the curriculum.
*W. Ketterle*

**8.S50 Special Subject: Physics**
Prereq: None
U (IAP)
Not offered regularly; consult department
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.S998 Special Subject: Physics**
Prereq: None
U (Fall, Spring)
Not offered regularly; consult department
2-0-1 units

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

**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*