DEPARTMENT OF EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES

The Department of Earth, Atmospheric, and Planetary Sciences offers a bachelor's degree in earth, atmospheric, and planetary sciences, and master's and doctoral degrees in atmospheric sciences, climate science, geology, geochemistry, geobiology, geophysics, and planetary sciences. In conjunction with the Computational Science and Engineering Program (CSE), the department offers a PhD in computational earth, atmospheric and planetary sciences (*https://catalog.mit.edu/interdisciplinary/graduate-programs/computational-science-engineering*). The department also participates in the MIT-WHOI Joint Program in Oceanography/Applied Ocean Science and Engineering (*https://catalog.mit.edu/interdisciplinary/graduate-programs/joint-program-woods-hole-oceanographic-institution*) with doctoral degree programs in chemical oceanography, physical oceanography, biological oceanography, and marine geology and geophysics.

Departmental programs apply physics, chemistry, and mathematics to the study of the Earth and planets in order to understand the processes that are active in the Earth's interior, oceans, and atmosphere, as well as the interiors and atmospheres of other planets. The department also uses the basic sciences to understand the past history of the Earth and planets. By combining the past history with models of present physical, biological, and chemical processes, faculty and students work to develop an understanding of the dynamics of systems as diverse as the global climate system, regional tectonics and deformation, petroleum and geothermal reservoirs, and the solar system.

Research in the department is fundamental in nature, but underpins many of the most pressing societal questions of our time: climate and environmental change; natural hazards; natural resources; the origins of life both on Earth and elsewhere. Much of the research is interdisciplinary, so faculty, researchers, and students commonly cross discipline boundaries. Modern problems in these fields are approached by field measurements, laboratory studies, simulations, and theory. Experimental facilities for training and research are available not only in departmental laboratories such as the Earth Resources Laboratory, but also in MIT's interdepartmental laboratories (*https://catalog.mit.edu/mit/research*) such as the Center for Global Change Science, Kavli Institute for Astrophysics and Space Research, Lincoln Laboratory, Haystack Radio Observatory and Millstone Radar facility, and the Wallace Astrophysical and Geophysical Observatories, and in cooperating institutions such as the Woods Hole Oceanographic Institution.

Undergraduate Study

Bachelor of Science in Earth, Atmospheric, and Planetary Sciences (Course 12)

The Earth, Atmospheric, and Planetary Sciences Department offers undergraduate preparation for professional careers in a wide range of fields in geoscience (which includes geology, geophysics, geobiology, and geochemistry), atmospheric science, climate science, environmental systems, and planetary science and planetary astronomy.

The curriculum for the Bachelor of Science in Earth, Atmospheric, and Planetary Sciences (*https://catalog.mit.edu/degree-charts/earth-atmospheric-planetary-sciences-course-12*) ensures a fundamental background through general departmental subjects and advanced study in a concentration area chosen by the student. The student and advisor plan an appropriate and relevant selection of electives. Students are also required to take field and/or laboratory subjects, and to complete an independent research project as part of the degree requirements.

Bachelor of Science in Climate System Science and Engineering (1-12)

The Department of Civil and Environmental Engineering (*https://catalog.mit.edu/schools/engineering/civil-environmental-engineering*) and the Department of Earth, Atmospheric and Planetary Sciences (p. 3) offer a joint undergraduate degree program leading to the Bachelor of Science in Climate System Science and Engineering (*https://catalog.mit.edu/degree-charts/climate-system-science-engineering-course-1-12*). A detailed description of the requirements can be found under the section on Interdisciplinary Programs.

Double Major

Studies in physics, chemistry, biology, applied mathematics, and electrical or civil engineering are directly relevant preparation for work in earth, atmospheric, and planetary sciences. Students from these departments can arrange a program of study in Course 12 leading to a second major with subjects that strengthen their undergraduate program.

Five-Year Program

Students with strong academic records from the departments of Earth, Atmospheric, and Planetary Sciences, Chemistry, Physics, Mathematics, Civil and Environmental Engineering, Electrical Engineering and Computer Science, or Chemical Engineering, should be able to complete a Master of Science in Earth and Planetary Sciences, in Atmospheric Sciences, or in Ocean Sciences in one year of additional study, particularly if programs are arranged for this purpose from the beginning of the fourth year.

Applications for graduate enrollment in the department are considered any time after the beginning of the fourth year. Students

may receive the Bachelor of Science as soon as the requirements are completed, or may elect to defer the award for simultaneous presentation with the Master of Science.

Minor in Earth, Atmospheric, and Planetary Sciences

The Minor in Earth, Atmospheric, and Planetary Sciences provides an opportunity to complement or expand upon one's major by exploring in depth the natural processes that govern the structure and evolution of the Earth and planets. Areas of study include planetary surfaces, interiors, atmospheres, oceans, and biospheres. The EAPS Minor requires a solid foundation in two core subjects plus electives that create expertise in a particular area. Opportunities for field work, laboratory work, and independent study are an essential component of the minor.

Core Subjects		
Select two of the following:		24
12.001	Introduction to Geology	
12.002	Introduction to Geophysics and Planetary Science	
12.003	Introduction to Atmosphere, Ocean, and Climate Dynamics	
12.004	Introduction to Chemistry of Habitable Environments	
Select one of the following:		12
5.601 & 5.602	Thermodynamics I and Thermodynamics II and Kinetics	
18.03	Differential Equations [1]	
Restricted Electives		
Select at least 24 units in Course 12 subjects, approved by the minor advisor, to provide a depth of understanding and expertise in an EAPS discipline. [2]		24
Laboratory or Independent Study: Select one option from either of the following groups:		12-15
Laboratory		
12.110A & 12.110B	Sedimentary Environments and Sedimentology in the Field	
12.115 & 12.116	Field Geology and Analysis of Geologic Data	
12.307	Weather and Climate Laboratory	
12.373	Field Oceanography	
12.335	Experimental Atmospheric Chemistry	
12.410[J]	Observational Techniques of Optical Astronomy	
Independent Study		
12.IND	Independent Study	
12.UR	Undergraduate Research	
Total Units		**72-75**

1 *18.032 Differential Equations is also an acceptable option.*

2 *Consult the list of EAPS undergraduate subjects* (*https://catalog.mit.edu/subjects/12*).

Minor in Astronomy

The Earth, Atmospheric, and Planetary Sciences Department jointly offers a Minor in Astronomy (*https://catalog.mit.edu/interdisciplinary/undergraduate-programs/minors/astronomy*) with the Department of Physics (Course 8). A detailed description and list of requirements for this minor is available under Interdisciplinary Programs.

Inquiries

Additional information may be obtained from the department's Education Office, Room 54-912, 617-253-3381.

Graduate Study

The Department of Earth, Atmospheric, and Planetary Sciences offers opportunities for graduate study and research in a wide range of fields:

- Atmospheric chemistry
- Atmospheric dynamics
- Biogeochemistry
- Climate chemistry
- Climate dynamics
- Computational earth, atmospheric, and planetary sciences (in conjunction with the Computational Sciences and Engineering Program)
- Geology
- Geobiology
- Geochemistry
- Geophysics
- Paleoclimate
- Planetary sciences

Study in chemical, physical, and biological oceanography, as well as marine geology and geophysics, is offered in cooperation with the Joint Program with Woods Hole Oceanographic Institution (*http://mit.whoi.edu*).

Coursework during the first two years is the usual prelude to a thesis demonstrating that the student is capable of independent and creative research. The department offers the following degrees: a Master of Science, a Doctor of Philosophy, or a Doctor of Science in the field of specialization.

A graduate thesis may have either a theoretical, experimental, or observational focus. Modern laboratory facilities, computers, instrumentation, and extensive collections of specimens and data are available to students. Field study is an essential part of the graduate curriculum in geology, geophysics, and geochemistry,

and special arrangements may be made for summer employment and field research on departmental projects and with industrial organizations and government agencies. In atmospheric science and climate studies graduate study includes a mixture of theoretical and experimental studies sharing a common appreciation of the dynamics of the underlying processes.

Admission Requirements for Graduate Study

In addition to the general institute requirements for admission (*https://catalog.mit.edu/mit/graduate-education*) listed in the section on Graduate Education, the department requires preparation equivalent to the curriculum for the Bachelor of Science in Earth, Atmospheric, and Planetary Sciences at MIT for graduate studies in that field. For atmospheric sciences, climate studies, meteorology, and oceanography, the most essential element is a sound preparation in mathematics and physics, supplemented if possible by some chemistry. Students taking their undergraduate work at other institutions are advised to include in their programs the equivalent of the mathematics and physics contained in the MIT undergraduate curricula. If students are not fully prepared in certain of the fields or required subjects, they usually are asked to extend their studies in these areas while pursuing advanced work. The doctoral program can be entered without a Master of Science as a prerequisite.

Master of Science in Earth and Planetary Sciences, in Atmospheric Science, or in Climate Science

The General Degree Requirements (*https://catalog.mit.edu/mit/graduate-education*) for the degree of Master of Science in Earth and Planetary Sciences, in Atmospheric Science, or in Climate Science are described under Graduate Education. An individual program of study and research is arranged to suit the special background, needs, and goals of each student. The program is worked out in detail by the student with his or her personal faculty advisor and a departmental committee. There are no foreign language requirements for the degree.

Doctor of Philosophy and Doctor of Science in Earth, Atmospheric, and Planetary Sciences Fields

In consultation with a faculty advisor and a departmental committee, each student in the department's Doctor of Philosophy or Doctor of Science in an Earth, Atmospheric, and Planetary Science Field (*https://catalog.mit.edu/schools/science/#degreesandprogramstext*) program develops and follows a specialized program of study and research (*https://catalog.mit.edu/degree-charts/phd-earth-atmospheric-planetary-sciences*) tailored to their particular background, needs, and goals. A doctoral candidate's program should be broad and may include formal study in other departments in addition to the specialized subjects that prepare the candidate for thesis research. There is no foreign language requirement for the degree. Thesis research normally begins immediately after successful completion of the general examination by the end of the second year. The general examination is intended to test the candidate's aptitude and preparation for independent research.

Thesis research is closely supervised by one or more faculty members interested in and knowledgeable about the research topic, who are chosen by the student and may be members of other departments. The thesis is expected to meet high professional standards, and to be a significant original contribution to the scientific field.

Upon successful completion of the student's designated program and thesis defense, the student is awarded the Doctor of Philosophy or Doctor of Science in the designated field of earth, atmospheric, and planetary sciences.

Interdisciplinary Programs

Computational Science and Engineering Doctoral Program

The Doctoral Program in Computational Science and Engineering (CSE PhD) (*https://cse.mit.edu/programs/phd*) allows students to specialize in a computation-related field of their choice through focused coursework and a doctoral thesis through a number of participating host departments. The CSE PhD program is administered jointly by the Center for Computational Science and Engineering (CCSE) and the host departments, with the emphasis of thesis research activities being the development of new computational methods and/or the innovative application of computational techniques to important problems in engineering and science. For more information, see the full program description (*https://catalog.mit.edu/interdisciplinary/graduate-programs/computational-science-engineering*) under Interdisciplinary Graduate Programs.

Joint Program with the Woods Hole Oceanographic Institution

The Joint Program with the Woods Hole Oceanographic Institution (WHOI) (*http://mit.whoi.edu*) is intended for students whose primary career objective is oceanography or oceanographic engineering. Students divide their academic and research efforts between the campuses of MIT and WHOI. Joint Program students are assigned an MIT faculty member as academic advisor; thesis research may be advised by MIT or WHOI faculty. While in residence at MIT, students follow a program similar to that of other students in their home department. The program is described in more detail (*https://catalog.mit.edu/interdisciplinary/graduate-programs/joint-program-woods-hole-oceanographic-institution*) under Interdisciplinary Graduate Programs.

Financial Support

The department offers a considerable number of research and teaching assistantships each year. Research assistants work on one of the many research projects in the department, often related to the student's thesis research. Teaching assistants assist in laboratory instruction or in the preparation of teaching materials and the grading of papers.

The department also offers several fellowships beyond normal teaching and research assistantships. Selection of individuals is based on the excellence of the applicant's record.

Inquiries
Additional information regarding academic and current research programs in the department, admission requirements, assistantship appointments, and financial aid may be obtained by writing to the department's Education Office, Room 54-912, 617-253-3381.

Research Laboratories and Programs

The department's faculty, staff, and students are engaged in a wide variety of research projects in the laboratories of individual faculty members and in the departmental laboratories described below. Many also participate in the activities of interdisciplinary laboratories such as the Center for the Global Change Science and the Joint Program on the Science and Policy of Global Change, described in the section on Research and Study (*https://catalog.mit.edu/mit/research*).

Earth Resources Laboratory
The Earth Resources Laboratory (ERL) (*http://erl.mit.edu*) is MIT's primary home for research and education focused on sub-surface energy resources. Through integration across disciplines, departments, and school boundaries, and with support from federal agencies and a consortium of energy companies, ERL addresses questions concerning hydrocarbon exploration and production, geothermal energy, CO_2 sequestration, and near-surface environments.

ERL's faculty, research staff, and students work with a variety of methodologies (including geophysical imaging, rock physics and chemistry, multiphase flow, geomechanics, microseismics, and remote sensing) to obtain a holistic understanding of sub-surface reservoirs—their structure, the geological materials of which they are made, the fluids that flow through them, and changes that occur in response to production.

Building on a rich tradition, ERL aims to produce tomorrow's industry leaders through rigorous disciplinary education and broad exposure to the earth sciences, mathematics, and engineering.

Professor Laurent Demanet is the current director of ERL. For further information, please visit ERL website (*http://erl.mit.edu*).

George R. Wallace, Jr., Astrophysical Observatory
The George R. Wallace, Jr., Astrophysical Observatory (*http://web.mit.edu/wallace*) is a versatile facility for research and teaching optical astronomy. The observatory located in Westford, MA, has several optical telescopes ranging from 24-in to 8-in diameters and modern instrumentation. The telescopes are used in formal instruction; faculty, staff, and student research projects; and as testbeds for instrumentation to be used with larger telescopes.

Further information on the Wallace Observatory may be obtained by contacting Dr. Michael Person (*mjperson@mit.edu*), 54-418, 617-452-2304.

George R. Wallace, Jr., Geophysical Observatory
The George R. Wallace, Jr., Geophysical Observatory is a unique research facility designed to monitor ground motions and to aid in the development and testing of new seismic and other geophysical instrumentation. It is also a key component of MIT's five-station seismic network in New England.

Located 35 miles north of Boston in Westford, MA, the observatory has a large, multi-room underground vault and a surface control room. The vault has a controlled temperature environment and instrument piers resting directly on the basement granite. The observatory contains sensitive seismometers and instruments for monitoring ground tilts and the earth's tidal motions. The surface building houses a work area and control and recording instruments. Data from the observatory are telemetered directly to the Earth Resources Laboratory of the Department of Earth, Atmospheric, and Planetary Sciences. The data from the observatory and the New England Seismic Network are recorded, displayed, and analyzed by three dedicated COMPAQ computers, which are also connected to workstations to facilitate data sharing and transfers. Data from the observatory along with the numerous resources of the department provide a unique facility for undergraduates, graduate students, and staff to pursue research concerning the interior of the earth.

Further information may be obtained by contacting EAPS Headquarters, 55-101, 617-253-2127.

Faculty and Teaching Staff

Robert D. van der Hilst, PhD
Schlumberger Professor of Geosciences
Head, Department of Earth, Atmospheric, and Planetary Sciences

David McGee, PhD
Associate Professor of Paleoclimate
Associate Head for Diversity, Equity, and Inclusion

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Michael J. Follows, PhD
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Professor of Atmospheric Chemistry and Climate Science
Professor of Chemistry

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Michael J. Person, PhD
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Lecturer in Earth, Atmospheric, and Planetary Sciences

Technical Instructors
Timothy Brothers, BS
Technical Instructor in Earth, Atmospheric, and Planetary Sciences

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Srinivas (Sai) Ravela, PhD
Principal Research Scientist of Earth, Atmospheric and Planetary Sciences

Professors Emeriti

Charles C. Counselman III, PhD
Professor Emeritus of Planetary Sciences

J. Brian Evans, PhD
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Timothy L. Grove, PhD
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Richard Siegmund Lindzen, PhD
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John B. Southard, PhD
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Peter H. Stone, PhD
Professor Emeritus of Climate Dynamics

Roger Everett Summons, PhD
Professor Emeritus of Geobiology

M. Nafi Toksöz, PhD
Professor Emeritus of Geophysics

Carl Wunsch, PhD
Professor Emeritus of Physical Oceanography

Undergraduate Subjects

Core and General Science Subjects

12.00 Frontiers and Careers in Earth, Planets, Climate, and Life
Prereq: None
U (Spring)
Not offered regularly; consult department
2-0-0 units

Provides a broad overview of topics, technologies, and career paths at the forefront of Earth, Atmospheric and Planetary Sciences. Introduces the complex interplay between physics, mathematics, chemistry, biology, and computational methods used to study processes associated with a changing Earth and climate, distant planets, and life. Sessions guided by faculty members discussing current research problems, and by EAPS alumni describing how their careers have evolved. Subject can count toward the 6-unit discovery-focused credit limit for first year students.
T. Herring

12.000 Solving Complex Problems
Prereq: None
U (Fall)
1-2-6 units

Provides an opportunity for entering freshmen to gain firsthand experience in integrating the work of small teams to develop effective solutions to complex problems in Earth system science and engineering. Each year's class explores a different problem in detail through the study of complementary case histories and the development of creative solution strategies. Includes exercises in website development, written and oral communication, and team building. Subject required for students in the Terrascope freshman program, but participation in Terrascope is not required of all 12.000 students. Students who pass 12.000 are eligible to participate in the Terrascope field trip the following spring. Limited to freshmen.
D. McGee, A. Epstein

12.001 Introduction to Geology
Prereq: None
U (Fall)
3-4-5 units. REST

Major minerals and rock types, rock-forming processes, and time scales. Temperatures, pressures, compositions, structure of the Earth, and measurement techniques. Geologic structures and relationships observable in the field. Sediment movement and landform development by moving water, wind, and ice. Crustal processes and planetary evolution in terms of global plate tectonics with an emphasis on ductile and brittle processes. Includes laboratory exercises on minerals, rocks, mapping, plate tectonics, rheology, glaciers. Two one-day field trips (optional).
T. Bosak, O. Jagoutz

12.002 Introduction to Geophysics and Planetary Science
Prereq: Calculus II (GIR) and Physics II (GIR)
U (Spring)
3-1-8 units. REST

Study of the structure, composition, and physical processes governing the terrestrial planets, including their formation and basic orbital properties. Topics include plate tectonics, earthquakes, seismic waves, rheology, impact cratering, gravity and magnetic fields, heat flux, thermal structure, mantle convection, deep interiors, planetary magnetism, and core dynamics. Suitable for majors and non-majors seeking general background in geophysics and planetary structure.
C. Cattania, G. Stucky de Quay

12.003 Introduction to Atmosphere, Ocean, and Climate Dynamics
Prereq: Calculus II (GIR) and Physics I (GIR)
U (Spring)
3-0-9 units. REST

Introduces the dynamical processes that govern the atmosphere, oceans, and climate. Topics include Earth's radiation budget, convection and clouds, the circulation of the atmosphere and ocean, and climate change. Illustrates underlying mechanisms through laboratory demonstrations with a rotating table, and through analysis of atmospheric and oceanic data.
T. Cronin

12.004 Introduction to Chemistry of Habitable Environments
Prereq: Chemistry (GIR)
U (Fall)
4-0-8 units. REST

Introduction to the central roles of chemistry and biology on Earth that underlie modern climate, climate history, and global elemental cycles. Topics include the interactions of chemistry and biology in atmospheric, aquatic, and terrestrial systems. Fundamental principles of redox, equilibria, and acid/base reactions are explored via their links in the Earth system and with respect to climate feedbacks and ecosystem dynamics, providing perspectives for the future of our planet and beyond.
A. R. Babbin

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

Introduction to nonlinear dynamics and chaos in dissipative systems. Forced and parametric oscillators. Phase space. Periodic, quasiperiodic, and aperiodic flows. Sensitivity to initial conditions and strange attractors. Lorenz attractor. Period doubling, intermittency, and quasiperiodicity. Scaling and universality. Analysis of experimental data: Fourier transforms, Poincare sections, fractal dimension, and Lyapunov exponents. Applications to mechanical systems, fluid dynamics, physics, geophysics, and chemistry. See 12.207[J]/18.354[J] for Nonlinear Dynamics: Continuum Systems.
D. Rothman

12.007 Geobiology: History of Life on Earth
Prereq: None
U (Spring)
3-0-9 units

Surveys the interactive Earth system: biology in geologic, environmental and climate change throughout Earth's history. Introduces the concept of "life as a geological agent" and examines the interaction between biology and the Earth system during the roughly 4 billion years since life first appeared. Topics include the origin of the solar system and the early Earth atmosphere; the origin and evolution of life and its influence on climate up through and including the modern age and the problem of global warming; the global carbon cycle; and astrobiology.
T. Bosak, G. Fournier

12.009[J] Nonlinear Dynamics: The Natural Environment
Same subject as 18.352[J]
Prereq: Calculus II (GIR) and Physics I (GIR); *Coreq: 18.03*
U (Fall)
Not offered regularly; consult department
3-0-9 units

Analyzes cooperative processes that shape the natural environment, now and in the geologic past. Emphasizes the development of theoretical models that relate the physical and biological worlds, the comparison of theory to observational data, and associated mathematical methods. Topics include carbon cycle dynamics; ecosystem structure, stability and complexity; mass extinctions; biosphere-geosphere coevolution; and climate change. Employs techniques such as stability analysis; scaling; null model construction; time series and network analysis.
D. H. Rothman

12.010 Computational Methods of Scientific Programming
Prereq: Calculus II (GIR) and Physics I (GIR)
U (Fall)
4-0-8 units

Introductory subject exposes students to modern programming methods and techniques used in practice by physical scientists today. Emphasis on code design, algorithm development/verification, and comparative advantages/disadvantages of different languages (including Python, Julia and C/C++) and tools (including Jupyter, machine-learning from data or models, cloud and high-performance computing workflows). Students are introduced to and work with common programming tools, types of problems, and techniques for solving a variety of data analytic and equation modeling scenarios from real research: examination visualization techniques; basic numerical analysis; methods of dissemination and verification; practices for reproducible work, version control, documentation, and sharing/publication. No prior programming experience is required.
T. Herring, C. Hill

12.011[J] Archaeological Science
Same subject as 3.985[J], 5.24[J]
Prereq: Chemistry (GIR) or Physics I (GIR)
U (Spring)
3-1-5 units. HASS-S

See description under subject 3.985[J].
M. Tarkanian, J. Meanwell

12.012 MatLab, Statistics, Regression, Signal Processing
Subject meets with 12.444
Prereq: None. *Coreq: 18.06*
U (Fall)
3-0-9 units

Introduces the basic tools needed for data analysis and interpretation in the Geosciences, as well as other sciences. Composed of four modules, targeted at introducing students to the basic concepts and applications in each module. MatLab: Principles and practice in its uses, script and function modules, basic approaches to solving problems. Statistics: Correlation, means, dispersion, precision, accuracy, distributions, central limit theorem, skewness, probability, Chi-Square, Gaussian and other common distributions used in hypothesis testing. Regression: Random and grid search methods, basic least squares and algorithms applicable to regression, inversion and parameter estimation. Signal Processing: Analog and digital signals, Z-transform, Fourier series, fast Fourier transforms, spectral analysis leakage and bias, digital filtering. Students taking the graduate version complete different assignments.
T. A. Herring, S. Ravela

12.021 Earth Science, Energy, and the Environment
Prereq: Calculus I (GIR), Chemistry (GIR), and Physics I (GIR)
U (Fall)
Not offered regularly; consult department
3-1-8 units

Provides understanding of the Earth System most relevant to production of our planet's natural energy resources, including the physics, chemistry, and biology of conventional and alternative energy sources. Includes a broad overview of traditional and alternative energy sources: hydrocarbons (conventional and unconventional), nuclear, geothermal, hydroelectric, and wind and tides, along with their potentials and limitations. Develops detailed knowledge of the formation, concentration, and production of fossil and nuclear fuels, as well as the waste products associated with their consumption. An examination of conventional and alternative energy sources includes the environmental issues associated with the exploitation of these resources, both regional and global.
B. H. Hager

12.031[J] Fundamentals of Ecology
Same subject as 1.018[J], 7.30[J]
Prereq: None
U (Fall)
4-0-8 units. REST

See description under subject 1.018[J].
M. Follows, D. Des Marais

12.080 Experiential Learning in EAPS
Prereq: None
U (Fall, IAP, Spring, Summer)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

For Course 12 students participating in off-campus professional experiences related to their course of study. Before registering for this subject, students must have an offer from a company or organization, must identify an EAPS advisor, and must receive prior approval from their advisor. Upon completion of the experience, student must submit a letter from the company or organization describing what the student accomplished, along with a substantive final report from the student approved by the EAPS advisor. Consult departmental academic office.
EAPS Faculty

12.086 Modeling Environmental Complexity
Subject meets with 12.586
Prereq: 18.03
U (Spring)
3-0-9 units

Introduction to mathematical and physical models of environmental processes. Emphasis on the development of macroscopic continuum or statistical descriptions of complex microscopic dynamics. Problems of interest include: random walks and statistical geometry of landscapes; percolation theory and transport in disordered media; fractals, scaling, and universality; ecological dynamics and the structure of ecosystems, food webs, and other natural networks; kinetics of biogeochemical cycles. Appropriate for advanced undergraduates. Beginning graduate students are encouraged to register for 12.586. Students taking the graduate version complete different assignments.
D. H. Rothman

12.090 Current Topics in Earth, Atmospheric, and Planetary Sciences
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall, Spring)
Units arranged
Can be repeated for credit.

Laboratory or field work in earth, atmospheric, and planetary sciences. Consult with department Education Office.
EAPS Faculty

12.091 Current Topics in Earth, Atmospheric, and Planetary Sciences
Prereq: Permission of instructor
Acad Year 2024-2025: U (IAP)
Acad Year 2025-2026: Not offered
Units arranged [P/D/F]
Can be repeated for credit.

Laboratory or field work in earth, atmospheric, and planetary sciences. Consult with department Education Office.
EAPS Faculty

12.092 Current Topics in Geology and Geochemistry
Prereq: None
U (Fall, IAP, Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Laboratory or field work in geology and geochemistry. Consult with department Education Office.
Staff

12.093 Current Topics in Geology and Geochemistry
Prereq: Permission of instructor
U (Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Laboratory or field work in geology and geochemistry. To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty

12.094 Current Topics in Geophysics
Prereq: Permission of instructor
U (Fall, IAP, Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Laboratory or field work in geophysics. Consult with department Education Office.
EAPS Faculty

12.095 Current Topics in Geophysics
Prereq: Permission of instructor
U (Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Laboratory, data analysis, system modeling or field work in geophysics. To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty

12.096 Current Topics in Atmospheric Science and Oceanography
Prereq: Permission of instructor
U (Fall, IAP, Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Laboratory or field work in atmospheric science and oceanography. To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty

12.097 Current Topics in Atmospheric Science and Oceanography
Prereq: Permission of instructor
U (Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Laboratory or field work in atmospheric science and oceanography. To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty

12.098 Current Topics in Planetary Science
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Laboratory or field work in planetary science. To be arranged with department faculty. Consult with department Education Office.
EAPS Staff

12.099 Current Topics in Planetary Science
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Laboratory or field work in planetary science. To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty

12.C25[J] Real World Computation with Julia
Same subject as 1.C25[J], 6.C25[J], 16.C25[J], 18.C25[J], 22.C25[J]
Prereq: 6.100A, 18.03, and 18.06
U (Fall)
3-0-9 units

See description under subject 18.C25[J].
A. Edelman, R. Ferrari, B. Forget, C. Leiseron,Y. Marzouk, J. Williams

Geology and Geochemistry

12.100 Plate Tectonics and Climate (New)
Subject meets with 12.475
Prereq: 12.001 or permission of instructor
U (Fall)
3-0-6 units

Explores plate tectonics and the fundamental relationship between tectonic systems and global climate. Provides an in-depth study of plate tectonics, encompassing sea floor spreading, continental rifting, mountain and basin formation, and subduction. Examines the profound effects of tectonic activity on global climate, emphasizing the critical links between solid earth processes and long-term climate change and offering a holistic view of our planet's intricate systems. Regional case studies present examples of the complex interconnections along Earth's long history. An optional weekend field trip brings concepts encountered in class into tangible, real-world context. Expectations differ for students taking graduate version.
O. Jagoutz, L. H. Royden, K. Bergmann

12.104 Geochemistry of Natural Waters
Subject meets with 12.494
Prereq: Calculus II (GIR)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-2-7 units

Equips students with the fundamental skills to identify major controls on the chemistry of waters on the Earth. Students examine key concepts, theories and practical tools (e.g., pH, Eh, alkalinity, surface charge, speciation, and carbonate equilibrium) and apply them as tools to understand and make predictions for the biogeochemical cycles of the Earth systems. Students taking graduate version complete additional assignments.
S. Ono

12.108 Earth Materials: Minerals and Rocks
Prereq: Chemistry (GIR)
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
3-4-5 units

Provides an integrated survey of rocks and rock-forming minerals. Introduces the fundamentals of crystal structure and mineral chemistry and explore mineral and rock formation mechanisms across Earth and planetary surfaces and interiors. Links mineral assemblages to the chemical compositions of rocks within the Earth's crust and upper mantle and to specific tectonic environments. Students investigate the chemistry and physics of rock formation mechanisms, crust and mantle melting dynamics, and the geochemical and mineralogical signatures of igneous rocks and metamorphic processes. Laboratory component includes both specimen-level work and petrography.
N. Nie

12.110A Sedimentary Environments
Subject meets with 12.465A
Prereq: 12.001 or 12.11
Acad Year 2024-2025: U (Spring; first half of term)
Acad Year 2025-2026: Not offered
2-1-3 units. Partial Lab

Covers the basic concepts of sedimentation from the properties of individual grains to large-scale basin analysis. Lectures cover sediment textures and composition, fluid flow and sediment transport, and formation of sedimentary structures. Depositional models, for both modern and ancient environments are a major component and are studied in detail with an eye toward interpretation of depositional processes and reconstructing paleoenvironments from the rock record. Satisfies 6 units of Institute Laboratory credit. Students taking graduate version complete additional assignments.
K. Bergmann

12.110B Sedimentology in the Field
Subject meets with 12.465B
Prereq: 12.110A
U (Spring; second half of term)
2-2-5 units. Partial Lab
Can be repeated for credit.

Examines the fundamentals of sedimentary deposits and geological reasoning through first hand fieldwork. Students practice methods of modern geological field study off-campus during a required trip over spring break making field observations, measuring stratigraphic sections and making a sedimentological map. Relevant topics introduced are map and figure making in ArcGIS and Adobe Illustrator and sedimentary petrology. Culminates in an oral and written report built around data gathered in the field. Field sites and intervals of geologic time studied rotate annually and include Precambrian, Phanerozoic and Modern depositional environments. Satisfies 6 units of Institute Laboratory credit. May be taken multiple times for credit. Students taking graduate version complete additional assignments.
K. Bergmann

12.113 Structural Geology
Prereq: 12.001
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-3-6 units

Introduces mechanics of rock deformation. Discusses recognition, interpretation, and mechanics of faults, folds, structural features of igneous and metamorphic rocks, and superposed deformations. Introduces regional structural geology and tectonics. Laboratory includes techniques of structural analysis, recognition and interpretation of structures on geologic maps, and construction of interpretive cross sections.
M. Pec

12.115 Field Geology
Prereq: 12.113
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (IAP)
0-9-0 units. Partial Lab

Introduction to the methods of modern geological field study off-campus during an intensive two-week experience. Exercises include geological and geomorphological mapping on topographic and photographic base maps of a wide variety of bedrock and surficial rocks. Where feasible, geochemical and geophysical field measurements are corrrelated with geology. Location is usually in the western US. Contact department regarding travel fee and resources for funding opportunities. Meets with 12.482 when offered concurrently. Satisfies 9 units of Institute Laboratory credit.
O. Jagoutz

12.116 Analysis of Geologic Data
Prereq: 12.115
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
0-2-4 units. Partial Lab

Includes in-depth laboratory analysis of samples, interpretation of geological data, and where possible, geophysical and geochemical data. Includes the preparation of reports based on the field studies conducted in 12.115 during January; report generally exceeds 30 pages in length and includes one major revision and rewrite. Instruction in writing techniques provided. Contact department regarding travel fee and resources for funding opportunities. Satisfies 3 units of Institute Laboratory credit.
O. Jagoutz

12.117A Field Geobiology I
Subject meets with 12.487A
Prereq: None. *Coreq: 12.001 or 12.007*
U (Spring; first half of term)
Not offered regularly; consult department
2-1-3 units

Examines basic biological processes that operate in sediments. Lectures cover biological, physical and chemical processes that influence the formation and stabilization of sediments, including biomineralization, weathering, erosion, the formation of sedimentary structures and interactions with sediments, flow, and the cycles of nutrients. Lab covers analytical methods used to examine microbial processes, bioinformatic methods used to analyze microbial communities, and techniques used to analyze sediment grain sizes and chemistry. Readings and discussions provide preparation for the 12.117B field trip to a modern sedimentary environment. Enables students to interpret processes in modern sedimentary environments, reconstruct similar processes in the rock record, collect appropriate samples in the field, and analyze microbiological data. Students taking graduate version complete additional assignments.
T. Bosak

12.117B Field Geobiology II
Subject meets with 12.487B
Prereq: 12.117A
U (Spring; second half of term)
Not offered regularly; consult department
2-2-5 units
Can be repeated for credit.

Teaches fundamentals of field observations and reasoning in geobiology/sedimentology during a required trip to a modern sedimentary environment over spring break, followed by laboratory analyses of collected samples. Students make observations, develop hypotheses, collect samples required to test their hypotheses and interact with lecturers and students investigating the sedimentology of the site. Upon return to MIT, students work on field samples to characterize the sediments, use the preliminary data to develop an understanding of the field site, and write research reports. Students taking graduate version write proposals that present a research question based on the field observations and subsequent analyses. Meets with 12.110B and 12.465B when those subjects examine modern sedimentary environments.
T. Bosak

12.119 Harnessing Power from Environmental Microbes and Chemical Gradients
Prereq: Biology (GIR), Chemistry (GIR), or 12.007
U (Spring)
Not offered regularly; consult department
2-2-5 units

Provides practical instruction on how to make living batteries. Lectures cover the basics of marine and freshwater chemistry and biogeochemistry (pH, redox potential, organic loading, free energy for growth, chemical profiles, sampling and measurement methods). Students explore sediment biogeochemistry by analyzing mineral types and grain sizes, setting up microbial enrichment cultures, and sampling and characterizing microbes and environmental chemistry by microscopy, chemical assays of pore fluids, and bioinformatics tools. Subsequent lab activities teach students to develop and use electrochemical tools to build microbial batteries that can power light sources and instruments. Discussion and reading cover real-world applications of microbial fuel cells.
T. Bosak, E. Boyle, S. Ono

12.12 Nature's Sandbox: The History of Ancient Environments, Climate, and Life
Prereq: None
Acad Year 2024-2025: U (Spring; second half of term)
Acad Year 2025-2026: Not offered
1-1-1 units

Series of field adventures to survey Earth's history and landscape through a combination of online and in-person instruction, with virtual field trips to Svalbard, Norway, the Death Valley area and Northern Minnesota. In these key sites, students explore the interactions between Earth's surface environments and life, and critical transitions in each. Includes weekly in-class paper discussions and experiential exercises. Three optional one-day field trips provide opportunity to explore the amazing sedimentary record preserved close to MIT. Subject can count toward the 6-unit discovery-focused credit limit for first year students.
K. Bergmann

12.141 Electron Microprobe Analysis
Prereq: None
U (IAP)
Not offered regularly; consult department
1-1-4 units

Introduction to the theory of x-ray microanalysis through the electron microprobe including ZAF matrix corrections. Techniques to be discussed are wavelength and energy dispersive spectrometry, scanning backscattered electron, secondary electron, cathodoluminescence, and x-ray imaging. Lab sessions involve use of the electron microprobe.
N. Chatterjee

12.163 Geomorphology
Subject meets with 12.463
Prereq: (Calculus I (GIR), Physics I (GIR), and 12.001) or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-3-6 units

Quantitative examination of processes that shape Earth's surface. Introduction to fluvial, hillslope, and glacial mechanics. Essentials of weathering, soil formation, runoff, erosion, slope stability, sediment transport, and river morphology. Landscape evolution in response to climatic and tectonic forcing. Application of terrestrial theory to planetary surfaces. Additional instruction in geographic information systems (GIS) and remote sensing analysis, field measurement techniques, and numerical modeling of surface processes. Students taking the graduate version complete different assignments.
T. Perron

12.170 Essentials of Geology
Subject meets with 12.470
Prereq: (Calculus II (GIR) and Physics II (GIR)) or permission of instructor
U (Fall)
Not offered regularly; consult department
4-0-8 units

Studies the geology of planetary interiors and surfaces, including plate tectonics, as a unifying theory of terrestrial geology, surface processes, and the Earth's interior. Covers igneous, metamorphic, and sedimentary processes associated with tectonic settings and the typical rock suites created; mineral and rock identification; and causes of compositional differences on many scales (mineral grains, rocks, regions of the Earth, different planets). Also addresses conditions required for melting and melting processes; rock structure and field techniques; and Earth history. Treatment of these topics includes discussions of the geochemical, petrologic, geochronological, experimental, or field techniques used to investigate them; the limitations of current geological techniques and geological controversies; and major geological expeditions, experiments, and studies from the past, along with their premises and results. Students taking graduate version complete additional assignments.
EAPS Staff

12.177 Astrobiology, Origins and Early Evolution of Life
Subject meets with 12.477
Prereq: Biology (GIR), Chemistry (GIR), or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

Provides an understanding of major areas of research into the problem of the origin of life on the early Earth from an astrobiological perspective. Topics include the timing, setting and conditions for the origin of life on the Hadean Earth; roles of planetary and extra-planetary processes; defining life; prebiotic chemistry; origins of nucleic acids and peptides; evolution of cellularity, replication, metabolism, and translation; establishment of the genetic code; biogenesis vs. ecogenesis; the nature of the last common ancestor of life; conceptualizing the "tree of life;" and the early evolution of the ancestors of bacteria, archaeal, and eukaryal lineages. Students taking graduate version complete an extra project.
G. Fournier

12.178 The Phylogenomic Planetary Record
Subject meets with 12.478
Prereq: None
Acad Year 2024-2025: U (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units

Introduces the tools of sequence-based phylogenetic analysis and molecular evolution in the context of studying events in Earth's deep past that have been preserved by genomes. Topics include basic concepts of cladistics, phylogeny and sequence evolution, construction of phylogenetic trees of genes and microbial lineages, molecular clocks, dating, and ancestral sequence reconstruction. Special attention to the evolutionary history of microbial metabolisms and their relationship to global biogeochemical cycles across Earth's history. Students taking graduate version complete additional assignments.
G. Fournier

Geophysics

12.201 Essentials of Global Geophysics
Subject meets with 12.501
Prereq: Physics II (GIR) and 18.03
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
4-0-8 units

Overview of basic topics in solid-earth geophysics, such as the Earth's rotation, gravity and magnetic field, seismology, and thermal structure. Formulation of physical principles presented in three one-hour lectures per week. Current applications discussed in an additional one-hour tutorial each week. Students taking graduate version complete different assignments.
R. van der Hilst

12.202 Flow, Deformation, and Fracture in Earth and Other Terrestrial Bodies
Subject meets with 12.502
Prereq: Calculus II (GIR) and Physics I (GIR)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-2-7 units

Covers fundamentals of deformation and fracture of solids and the flow of viscous fluids. Explores spatial scales from molecular to planetary, and time scales from fractions of a second to millions of years, to understand how and why natural materials on Earth and other terrestrial bodies respond to applied forces. Fundamental concepts include the principles of continuum mechanics, tensor representation of physical properties, forces, tractions, stresses, strain theory, elasticity, contact problems, fracture and friction, and viscous flow and rheological models (plasticity, viscosity, viscoelasticity, elasto-plasticity). Students gather, analyze and interpret data using existing theoretical models. Includes a significant laboratory component that provides practical experience with experimental measurements and tests students' acquired theoretical knowledge. Students taking graduate version complete different assignments.
B. Minchew, M. Pec

12.203 Mechanics of Earth
Subject meets with 12.503
Prereq: Calculus II (GIR) and Physics I (GIR)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-2-7 units

Covers topics in the deformation and fracture of solids and the flow of viscous fluids. Explores spatial scales from molecular to planetary, and time scales from fractions of a second to millions of years, to understand how and why natural materials on Earth and other terrestrial bodies respond to applied forces. Introduces anelasticity, granular mechanics, poroelasticity, rate-and-state friction, transport properties of Earth materials (Darcy's law, Fick's law), brittle-ductile transitions, creep of polycrystalline materials, stored energy and dissipation, and convection. Prepares students to gather, analyze and interpret data using existing theoretical models. Through a significant laboratory component, students obtain practical experience with experimental measurements and test their acquired theoretical knowledge. Students taking graduate version complete different assignments.
B. Minchew, M. Pec

12.207[J] Nonlinear Dynamics: Continuum Systems
Same subject as 1.062[J], 18.354[J]
Subject meets with 18.3541
Prereq: Physics II (GIR) and (18.03 or 18.032)
U (Spring)
3-0-9 units

See description under subject 18.354[J].
B. Primkulov

12.210 Introduction to Seismology (New)
Subject meets with 12.510
Prereq: 18.075 or 18.085
U (Fall)
3-1-8 units

A basic study in seismology and the utilization of seismic waves for the study of Earth's interior. Introduces techniques necessary for understanding of elastic wave propagation in stratified media and for calculation of synthetic seismograms (WKBJ and mode summation). Ray theory; interpretation of travel times. (e.g., tomography); surface wave dispersion in layered media; Earth's free oscillations; and seismicity, (earthquake locations, magnitude, moment, and source properties). Students taking graduate version complete additional assignments.
W. Frank

12.211 Field Geophysics
Subject meets with 12.511
Prereq: 12.214 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (IAP; partial term)
1-4-1 units

Covers practical methods of modern geophysics, including the global positioning system (GPS), gravity, and magnetics. Field work is conducted in western US and includes intensive 10-day field exercise. Focuses on measurement techniques and their interpretation. Introduces the science of gravity, magnetics, and the GPS. Measures crustal structure, fault motions, tectonic deformations, and the local gravity and magnetic fields. Students perform high-precision measurements and participate in data analysis. Emphasizes principles of geophysical data collection and the relevance of these data for tectonic faulting, crustal structure, and the dynamics of the earthquake cycle. Students taking graduate version complete additional assignments.
W. Frank, B. Minchew, T. A. Herring

12.212 Field Geophysics Analysis (New)
Subject meets with 12.512
Prereq: 12.211
U (Spring; first half of term)
Not offered regularly; consult department
2-0-4 units

Focuses on in-depth data analysis and development of skills needed to report results both in writing and orally. Students use data collected in 12.211 to develop written and oral reports of the results, with each student focusing on a different area such as developing the geophysical modeling or synthesis of the results into other studies in the area. The final written and oral reports are combined into a comprehensive report and presentation of the field camp and its results. Students taking graduate version complete additional assignments.
W. Frank, B. Minchew

12.213 Alternate Energy Sources
Prereq: None
U (IAP)
Not offered regularly; consult department
1-4-1 units
Can be repeated for credit.

Explores a number of alternative energy sources such as geothermal energy (heat from the Earth's interior), wind, natural gas, and solar energy. Includes a field trip to visit sites where alternative energy is being harvested or generated. Content and focus of subject varies from year to year.
F. D. Morgan

12.214 Essentials of Field Geophysics
Subject meets with 12.507
Prereq: Physics II (GIR), 6.100A, and 18.03
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-3-6 units

Introduces students to the practical field application of various geophysical methods to studying Earth's near-surface and prepares students to undertake fieldwork that uses these methods. Methods covered include but are not limited to measuring seismic waves, gravity, precise positions (commonly referred to as GPS but formally known as GNSS), and topography using drones. Lab time involves local fieldwork to gain experience with the methods being taught. Students taking graduate version complete additional assignments.
B. Minchew, W. Frank

12.225 Mechanisms of Faulting and Earthquakes (New)
Subject meets with 12.525
Prereq: 12.002 and (12.010, 12.012, 18.C25[J], (6.100A and 6.100B), or permission of instructor)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

Explores the fundamental mechanics of faulting and earthquakes from four related perspectives: seismology, geodesy, geodynamics, and rheology. Topics to be covered include: the physical processes that control the rheology of faults, including friction and fracture; how these rheological processes are manifest in faulting and earthquakes in the earth from a geodynamics perspective; and how the mechanics of faulting and earthquakes are constrained by seismological and geodetic observations. Features both continental and oceanic examples of faulting and earthquakes. Students taking graduate version complete additional assignments.
C. Cattania

Atmospheres, Oceans, and Climate

12.300[J] Global Change Science
Same subject as 1.071[J]
Subject meets with 1.771
Prereq: 18.03
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

See description under subject 1.071[J].
E. Eltahir

12.301 Climate Science
Subject meets with 12.842
Prereq: Chemistry (GIR), 18.03, or permission of instructor
U (Fall)
3-0-9 units

Introduction to climate studies, including beginnings of the solar system, time scales, and climate in human history; methods for detecting climate change, including proxies, ice cores, instrumental records, and time series analysis; physical and chemical processes in climate, including primordial atmosphere, ozone chemistry, carbon and oxygen cycles, and heat and water budgets; internal feedback mechanisms, including ice, aerosols, water vapor, clouds, and ocean circulation; climate forcing, including orbital variations, volcanism, plate tectonics, and solar variability; climate models and mechanisms of variability, including energy balance, coupled models, and global ocean and atmosphere models; and outstanding problems. Students taking the graduate version complete different assignments.
A. Fiore, P. O'Gorman

12.306 Atmospheric Physics and Chemistry
Subject meets with 10.571[J], 12.806[J]
Prereq: (18.075 and (5.60 or 5.61)) or permission of instructor
U (Spring)
3-0-9 units

Introduction to the physics and chemistry of the atmosphere including experience with computer codes. Aerosols and theories of their formation, evolution, and removal. Gas and aerosol transport from urban to continental scales. Coupled models of radiation, transport, and chemistry. Solution of inverse problems to deduce emissions and removal rates. Emissions control technology and costs. Applications to air pollution and climate. Students taking the graduate version complete different assignments.
R. G. Prinn

12.307 Weather and Climate Laboratory
Prereq: Calculus II (GIR) and Physics I (GIR)
U (Spring)
1-4-7 units. Institute LAB

Engages students in projects involving rotating tank laboratory experiments, analysis of data on the sphere, and report writing and presentation. Project themes explore fundamentals of climate science and make contact points with major contemporary environmental challenges facing mankind. Examples include heat and moisture transport in the atmosphere; weather and weather extremes; aerosols, dust, and atmospheric pollution; ocean circulation and transport and plastics in the ocean. Develops skills for how to deal with noisy, imperfect data. Provides instruction and practice in written and oral communication.
L. Illari, J. Marshall

12.310 An Introduction to Weather Forecasting
Prereq: Calculus I (GIR) and Physics I (GIR)
U (IAP)
1-1-4 units

Basic principles of synoptic meteorology and weather forecasting. Analysis of hourly weather data and numerical weather prediction models. Regular preparation of weather forecasts.
L. Illari

12.314[J] Ocean Chemistry Change Laboratory (New)
Same subject as 5.009[J]
Prereq: Chemistry (GIR)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring; first half of term)
1-3-2 units. Partial Lab

Introduces marine chemistry and explores how human activity is aggressively modifying Earth's climate system. Familiarizes students with instrumentation, techniques, and concepts utilized to investigate the ocean. Through lab work, students apply general chemistry principles to marine systems and develop new understanding of specific research problems within ocean chemistry and biogeochemistry. Satisfies 3 units of Institute Laboratory credit.
A. Babbin

12.315 Atmospheric Radiation and Convection
Subject meets with 12.815
Prereq: 12.390 or permission of instructor
U (Spring)
3-0-9 units

Introduction to the physics of atmospheric radiation, remote sensing, and convection, including use of computer codes. Radiative transfer equation including emission and scattering, spectroscopy, Mie theory, and numerical solutions. Physics of dry and moist convection, including moist thermodynamics. Radiative-convective equilibrium. Solution of inverse problems in remote sensing of atmospheric temperature and composition. Students taking graduate version complete different assignments.
T. Cronin

12.318 Introduction to Atmospheric Data and Large-scale Dynamics
Subject meets with 12.818
Prereq: None. *Coreq: 12.390*
U (Fall)
3-3-6 units

Provides a general introduction to meteorological data and analysis techniques, and their use in the MIT Synoptic Laboratory to study the phenomenology and dynamics of large-scale atmospheric flow. Illustrates balance concepts as applied to the dynamics of frontal and synoptic scales, using real-time upper-air and surface station data and gridded analyzed fields. Uses advanced meteorological software packages to access, manipulate, and graphically display the data. Students taking graduate version complete different assignments.
L. Illari

12.320A[J] Introduction to Hydrology and Water Resources
Same subject as 1.070A[J]
Prereq: 1.060A; *Coreq: 1.061A and 1.106*
U (Fall; first half of term)
2-0-4 units

See description under subject 1.070A[J].
D. Entekhabi

12.320B[J] Introduction to Hydrology Modeling
Same subject as 1.070B[J]
Prereq: 1.070A[J]
U (Fall; second half of term)
2-0-4 units

See description under subject 1.070B[J].
D. Entekhabi

12.330[J] Fluid Physics
Same subject as 1.066[J], 8.292[J]
Prereq: 5.60, 8.044, or permission of instructor
U (Spring)
3-0-9 units

See description under subject 8.292[J].
L. Bourouiba

12.335 Experimental Atmospheric Chemistry
Subject meets with 12.835
Prereq: Chemistry (GIR)
U (Fall)
2-4-6 units. Institute LAB

Introduces the atmospheric chemistry involved in climate change, air pollution, and ozone depletion using a combination of interactive laboratory and field studies and simple computer models. Uses instruments for trace gas and aerosol measurements and methods for inferring fundamental information from these measurements. Provides instruction and practice in written and oral communication. Students taking the graduate version complete different assignments.
R. Prinn, S. Ono

12.336[J] Air Pollution and Atmospheric Chemistry
Same subject as 1.085[J]
Subject meets with 1.855
Prereq: 18.03
U (Fall)
Not offered regularly; consult department
3-0-9 units

See description under subject 1.085[J]. Recommended for upper-level undergraduate students.
C. Heald

12.338 Aerosol and Cloud Microphysics and Chemistry
Prereq: 1.085[J], 12.335, or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-9 units

Focuses on understanding how aerosol particles form droplets or ice crystals during several atmospheric processes: determining Earth's radiative balance; heterogeneous chemistry and acid rain; understanding where, when and how much precipitation occurs. Provides tools for understanding the physics of aerosol and cloud element motion; the interaction of particles with water vapor, including phase changes and droplet and ice nucleation; the chemical composition of particles and the effect on cloud formation processes; and the effect of cloud processing on aerosol chemistry. Discusses relevant topics of contemporary interest, e.g., geoengineering and weather modification and volcanic effects. Students taking the graduate version complete different assignments.
D. Cziczo

12.346[J] Global Environmental Negotiations
Same subject as IDS.062[J]
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
2-0-4 units

See description under subject IDS.062[J].
N. E. Selin

12.348[J] Global Climate Change: Economics, Science, and Policy
Same subject as 15.026[J]
Prereq: (Calculus II (GIR), 5.60, and 14.01) or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-6 units

See description under subject 15.026[J].
Staff

12.349 Mechanisms and Models of the Global Carbon Cycle
Subject meets with 12.849
Prereq: Calculus II (GIR) and Physics I (GIR)
U (Spring)
Not offered regularly; consult department
3-0-9 units

Addresses changes in the ocean, terrestrial biosphere and rocks modulation of atmospheric carbon dioxide on timescales from months to millions of years. Includes feedbacks between carbon cycle and climate. Combines hands-on data analysis with the formulation of simple models rooted in basic physical, chemical and biological principles. Students create individual "toy" global carbon cycle models. Students taking graduate version complete different assignments.
M. Follows

12.372 Elements of Modern Oceanography
Subject meets with 12.702
Prereq: Permission of instructor
U (Fall)
3-0-9 units

Examines a series of crosscutting topics that exemplify current directions in interdisciplinary oceanography. Focuses on current themes in oceanography, their interdisciplinary nature, and the role of ocean sciences in society. Introduces core concepts across the disciplines of biological, physical, and chemical oceanography as well as marine geology. Emphasizes the interdisciplinary aspects of these core concepts, the kinds of approaches and modes of thinking common to all of the disciplines, and the technological developments underpinning current advances. Students taking graduate version complete different assignments.
G. Lawson, A. Kirincich (WHOI)

12.373 Field Oceanography
Subject meets with 12.777
Prereq: Biology (GIR), Chemistry (GIR), and permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-7-5 units. Institute LAB

Provides an introduction to the biogeochemistry of the ocean, and the field techniques and methods used in its study. Emphasizes biogeochemistry and the interrelated nature of elemental cycling, but also examines physical transport and air-sea gas exchange. Covers multiple aspects related to field instrumentation and measurements, including nutrients, oxygen, the carbon system, temperature, and salinity. Presents microbial analyses, such as metagenomics. Includes a mandatory spring break field trip aboard a research vessel; opportunities for funded travel available. Students work in groups to propose a project over the week-long voyage that utilizes the field time to collect samples. During the second half of the term, students analyze and synthesize the data, and present it in a publication-quality manuscript. Students taking graduate version complete additional assignments. Enrollment limited.
A. R. Babbin

12.377 The History of Earth's Climate
Subject meets with 12.707
Prereq: Permission of instructor
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Studies the climate history of the Earth, from the formation of the early atmosphere and ocean to the present. Evaluates geochemical, sedimentological, and paleontological evidence for changes in ocean circulation, global temperatures, and atmospheric carbon dioxide levels. Covers theories and models of Phanerozoic climate change. Provides a long-term history of the global carbon cycle. Students taking graduate version complete different assignments.
D. McGee

12.384[J] Living Dangerously: Environmental Problems from 1900 to Today
Same subject as STS.055[J]
Prereq: None
U (Spring)
3-0-9 units. HASS-H; CI-H

Historical overview of the interactions between people and their environments in the past 100 years. Focuses on the accelerating human impact on Earth, starting in the late 19th century and continuing to the present day. Covers case studies showing how people have become aware of their impacts on the environment, and, in turn, the environment's impacts upon human society and what humans have done to mitigate damages. Topics include: food safety and security, industrial agriculture, pesticides, nuclear energy and warfare, lead, smog, ozone depletion, and climate change. Limited to 18.
S. Solomon, K. Brown

12.385 Science, Politics, and Environmental Policy
Subject meets with 11.373[J], 12.885[J]
Prereq: None
U (Fall)
3-0-9 units

Examines the role of science in US and international environmental policymaking. Surveys the methods by which scientists learn about the natural world; the treatment of science by experts, advocates, the media, and the public and the way science is used in legislative, administrative and judicial decision making. Through lectures, group discussions, and written essays, students develop a critical understanding of the role of science in environmental policy. Potential case studies include fisheries management, ozone depletion, global warming, smog, and endangered species. Students taking the graduate version complete different assignments. Limited to 22.
S. Solomon, J. Knox-Hayes

12.386[J] Environment and History
Same subject as 21H.185[J], STS.031[J]
Prereq: None
U (Spring)
Not offered regularly; consult department
3-0-9 units. HASS-S; CI-H

See description under subject 21H.185[J]. Enrollment limited.
K. Brown, S. Solomon

12.387[J] People and the Planet: Environmental Governance and Science
Same subject as 15.874[J], IDS.063[J]
Prereq: None
U (Fall)
3-0-6 units

Introduces governance and science aspects of complex environmental problems and approaches to solutions. Introduces quantitative analyses and methodological tools to analyze environmental issues that have human and natural components. Demonstrates concepts through a series of in-depth case studies of environmental governance and science problems. Students develop writing, quantitative modeling, and analytical skills in assessing environmental systems problems and developing solutions. Through experiential activities, such as modeling and policy exercises, students engage with the challenges and possibilities of governance in complex, interacting systems, including biogeophysical processes and societal and stakeholder interactions.
N. Selin, S. Solomon, J. Sterman

12.390 Fluid Dynamics of the Atmosphere and Ocean
Subject meets with 12.800
Prereq: 12.003
U (Fall)
3-0-9 units

Introduction to fluid dynamics. Students acquire an understanding of some of the basic concepts of fluid dynamics that are needed as a foundation for advanced coursework in atmospheric science, physical oceanography, ocean engineering, climate science, etc. Emphasizes fluid fundamentals, with an atmosphere/ocean twist. Students taking graduate version complete additional assignments.
A. Mahadevan, C. Cenedese

12.391 Current Topics in Earth, Atmospheric and Planetary Sciences
Prereq: Permission of instructor
G (IAP)
Units arranged [P/D/F]
Can be repeated for credit.

Laboratory or field work in earth, atmospheric, and planetary sciences. Consult with department Education Office.
EAPS Faculty

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

See description under subject 8.396[J]. Limited to 80.
A. Frebel

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

See description under subject 8.397[J]. Limited to 80.
D. Rigos

Planetary Science and Astronomy

12.400 Our Space Odyssey
Prereq: Physics I (GIR)
U (Spring)
3-0-9 units. REST

Traces historical and scientific advancement of our understanding of Earth's cosmic context. Introduces basic physical principles by which planets form and create their associated features of rings, satellites, diverse landscapes, atmospheres, and climates. Includes the physics of asteroids and comets and their orbital characteristics and links to meteorites. Considers one of the most fundamental questions - whether or not we are alone - by detailing the scientific exploration goals to be achieved at the Moon, Mars, and beyond.
J. de Wit

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

See description under subject 8.282[J].
M. Tegmark

12.409 Hands-On Astronomy: Observing Stars and Planets
Prereq: None
U (Spring)
1-3-2 units

Background for, and techniques of, visual observation and electronic imaging of the Moon, planets, satellites, stars, and brighter deep-space objects. Weekly outdoor observing sessions using 8-inch diameter telescopes when weather permits. Indoor sessions introduce skills necessary for observation. Introduction to contemporary observational astronomy including astronomical computing, image and data processing, and how astronomers work. Student must maintain a careful and complete written log which is graded. Consumes an entire evening each week; 100% attendance at observing sessions required to pass. Enrollment limited; priority to first-year students.
M. Person

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

Fundamental physical and optical principles used for astronomical measurements at visible wavelengths and practical methods of astronomical observations. Topics: astronomical coordinates, time, optics, telescopes, photon counting, signal-to-noise ratios, data analysis (including least-squares model fitting), limitations imposed by the Earth's atmosphere on optical observations, CCD detectors, photometry, spectroscopy, astrometry, and time variability. Project at Wallace Astrophysical Observatory. Written and oral project reports. Limited to 18; preference to Course 8 and Course 12 majors and minors.
M. Person, R. Teague

12.411 Astronomy Field Camp
Prereq: 12.410[J]
U (IAP)
0-6-3 units
Can be repeated for credit.

Individual research projects in planetary science and astrophysics, involving supervised work at Teide Observatory on the island of Tenerife, Spain. Projects may include observations made using observatory telescope facilities. Project topics and objectives vary from year to year. Written and oral reports required. Limited to 6.
M. Person

12.412 Meteorites, Cosmochemistry, and Solar System Formation
Subject meets with 12.612
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

A broad introduction to cosmochemistry, the study of the solar system formation from a geochemical perspective. Examines how the current meteorite records are used to gain information on the processes that happened in the early solar system. Topics include the origin of elements and isotopes, chemical fractionations of them during different processes, meteorite records, pre-solar grains, cosmochemical models for the solar system formation, chronology of planetary bodies from radioactive isotopes, and analytical techniques commonly used in cosmochemistry. Students taking graduate version complete additional assignments.
N. X. Nie

12.420 Essentials of Planetary Science
Subject meets with 12.601
Prereq: (8.03, 12.002, and 18.03) or permission of instructor
Acad Year 2024-2025: U (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units

Advanced applications of physical and chemical principles to the study of the solar system. Topics include terrestrial and giant planets, meteorites, asteroids, comets, Kuiper belt objects, rings, impact craters, interiors, surfaces, atmospheres, geomagnetism, cosmochemistry, remote sensing, formation and evolution of the solar system.
B. Weiss, J. De Wit

12.421 Physical Principles of Remote Sensing
Subject meets with 12.621
Prereq: Physics II (GIR) and 6.100A
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Introduction to the physics of remote sensing with applications to the study of the Earth, Moon, planets and other solar system bodies, as well as to emerging fields, such as autonomous navigation. Includes the principles of optical, thermal, radar and lidar remote sensing. Covers fundamental properties of electromagnetic waves; principles of electromagnetic scattering from real and idealized materials, including various types of surfaces and vegetation; interaction of electromagnetic radiation with the atmosphere; and thermal and microwave emission from various media. Discusses past, present, and future remote sensing platforms along with the fundamentals of orbital mechanics and data processing tools and methods. Assignments require students to write simple computer programs and plot mathematical functions. Students taking graduate version complete different assignments.
B. Minchew

12.422 Planetary Atmospheres
Subject meets with 12.622
Prereq: 12.003 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

Provides a basic understanding of the physics and chemistry of planetary atmospheres. Explores the formation and evolution of atmospheres, their structure and dynamics, and what is known about their chemical composition. Pays particular attention to their energy balance. Also presents the current state of understanding of exoplanet atmospheres. Students taking graduate version complete an additional research project.
J. de Wit

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

Presents basic principles of planet atmospheres and interiors applied to the study of extrasolar planets. Focuses on fundamental physical processes related to observable extrasolar planet properties. Provides a quantitative overview of detection techniques. Introduction to the feasibility of the search for Earth-like planets, biosignatures and habitable conditions on extrasolar planets. Students taking graduate version complete additional assignments.
S. Seager

12.43[J] Space Systems Engineering
Same subject as 16.83[J]
Prereq: Permission of instructor
U (Spring)
3-3-6 units

See description under subject 16.83[J].
K. Cahoy

12.431[J] Space Systems Development
Same subject as 16.831[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
2-10-6 units. Institute LAB

See description under subject 16.831[J].
Staff

Independent Research Subjects

12.UAR[J] Climate and Sustainability Undergraduate Advanced Research
Same subject as 1.UAR[J], 3.UAR[J], 5.UAR[J], 11.UAR[J], 15.UAR[J], 22.UAR[J]
Prereq: Permission of instructor
U (Fall, Spring)
2-0-4 units
Can be repeated for credit.

See description under subject 1.UAR[J]. Application required; consult MCSC website for more information.
D. Plata, E. Olivetti

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

Undergraduate research opportunities in Earth, Atmospheric, and Planetary Sciences.
Consult Department UROP Coordinator

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

Undergraduate research opportunities in Earth, Atmospheric, and Planetary Sciences.
Consult Department UROP Coordinator

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

Independent reading, laboratory, or fieldwork in Earth, Atmospheric, and Planetary Sciences. To be arranged by student and an appropriate EAPS faculty member. A written report may be required at the discretion of the advisor. Units arranged should reflect the project requirements.
Consult EAPS Education Office

12.TIP Thesis Preparation
Prereq: None
U (Fall, Spring)
2-0-4 units

Definition of and early-stage work on the thesis project. Students develop a written research proposal and begin writing the supporting text of the thesis concurrent with conducting research for the thesis project. Supervision of the writing continues into the spring term which concludes with an oral presentation of the research results.
J. Abbott

12.THU Undergraduate Thesis
Prereq: 12.TIP
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Program of research leading to the writing of a thesis; to be arranged by the student and an appropriate MIT faculty member.
EAPS Faculty

Graduate Subjects

12.44 Practical Experience
Prereq: None
G (Summer)
Units arranged
Can be repeated for credit.

For Course 12 students participating in off-campus professional experiences related to their research. Before registering for this subject, students must have an offer from a company or organization, must identify an EAPS advisor, and must receive prior approval from their advisor. Upon completion of the experience, student must submit a letter from the company or organization describing the what the student accomplished, along with a substantive final report from the student approved by the EAPS advisor. Consult departmental academic office.
EAPS Faculty

12.444 MatLab, Statistics, Regression, Signal Processing
Subject meets with 12.012
Prereq: 18.06
G (Fall)
3-0-9 units

Introduces the basic tools needed for data analysis and interpretation in the Geosciences, as well as other sciences. Composed of four modules, targeted at introducing students to the basic concepts and applications in each module. MatLab: Principles and practice in its uses, script and function modules, basic approaches to solving problems. Statistics: Correlation, means, dispersion, precision, accuracy, distributions, central limit theorem, skewness, probability, Chi-Square, Gaussian and other common distributions used in hypothesis testing. Regression: Random and grid search methods, basic least squares and algorithms applicable to regression, inversion and parameter estimation. Signal Processing: Analog and digital signals, Z-transform, Fourier series, fast Fourier transforms, spectral analysis leakage and bias, digital filtering. Students taking the graduate version complete different assignments.
T. A. Herring, S. Ravela

12.446 Teaching Experience in EAPS
Prereq: None
G (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Development of teaching skills through practical experience in laboratory, field, recitation, or classroom teaching under faculty member oversight. Credit for this subject may not be used for any degree granted by Course 12. Total enrollment limited by availability of suitable teaching assignments.
EAPS Faculty

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

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

Geology and Geochemistry

12.450 Seminar in Geology and Geochemistry
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

Seminar on topics of current interest in geology and geochemistry. Required background preparation for students taking pre-doctoral general examinations in these subjects.
Geology and Geochemistry Staff

12.451 Seminar in Regional Tectonics
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
3-0-6 units
Can be repeated for credit.

Applies techniques of tectonic synthesis to study the roles of particular orogenic belts in global plate tectonics. Treats different applications in different terms, so that the subject may be taken repeatedly to learn the range of orogenic responses to temporal and spatial variations of activity at plate boundaries.
B. C. Burchfiel, L. H. Royden

12.456 Seminar in Rock Mechanics
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

Discussion of current research or advanced topics in continental tectonics, rock mechanics, or experimental structural geology.
EAPS Staff

12.463 Geomorphology
Subject meets with 12.163
Prereq: (Calculus I (GIR), Physics I (GIR), and 12.001) or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-3-6 units

Quantitative examination of processes that shape Earth's surface. Introduction to fluvial, hillslope, and glacial mechanics. Essentials of weathering, soil formation, runoff, erosion, slope stability, sediment transport, and river morphology. Landscape evolution in response to climatic and tectonic forcing. Application of terrestrial theory to planetary surfaces. Additional instruction in geographic information systems (GIS) and remote sensing analysis, field measurement techniques, and numerical modeling of surface processes. Students taking the graduate version complete different assignments.
T. Perron

12.465A Sedimentary Environments
Subject meets with 12.110A
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring; first half of term)
Acad Year 2025-2026: Not offered
2-1-3 units

Covers the basic concepts of sedimentation from the properties of individual grains to large-scale basin analysis. Lectures cover sediment textures and composition, fluid flow and sediment transport, and formation of sedimentary structures. Depositional models, for both modern and ancient environments are a major component and are studied in detail with an eye toward interpretation of depositional processes and reconstructing paleoenvironments from the rock record. Students taking graduate version complete additional assignments.
K. Bergmann

12.465B Sedimentology in the Field
Subject meets with 12.110B
Prereq: 12.456 or permission of instructor
G (Spring; second half of term)
2-2-5 units
Can be repeated for credit.

Examines the fundamentals of sedimentary deposits and geological reasoning through first hand fieldwork. Students practice methods of modern geological field study off-campus during a required trip over spring break making field observations, measuring stratigraphic sections and making a sedimentological map. Relevant topics introduced are map and figure making in ArcGIS and Adobe Illustrator and sedimentary petrology. Culminates in an oral and written report built around data gathered in the field. Field sites and intervals of geologic time studied rotate annually and include Precambrian, Phanerozoic and Modern depositional environments. May be taken multiple times for credit. Students taking graduate version complete additional assignments.
K. Bergmann

12.467 Seminar in Geomorphology
Prereq: Permission of instructor
G (Spring)
2-0-1 units
Can be repeated for credit.

Discussion of current research or advanced topics in landscape evolution, surface hydrology, mechanics of sediment transport, basin analysis, or experimental geomorphology. Advanced instruction in process geomorphology.
T. Perron

12.470 Essentials of Geology
Subject meets with 12.170
Prereq: (Calculus II (GIR) and Physics II (GIR)) or permission of instructor
G (Fall)
Not offered regularly; consult department
4-0-8 units

Geology of planetary interiors and surfaces, including plate tectonics, as a unifying theory of terrestrial geology, surface processes, and the Earth's interior. Igneous, metamorphic, and sedimentary processes associated with tectonic settings and the typical rock suites created. Mineral and rock identification. Causes of compositional differences on many scales: mineral grains, rocks, regions of the Earth, different planets. Conditions required for melting and melting processes. Rock structure and field techniques. Earth history. Treatment of these topics includes discussions of the geochemical, petrologic, geochronological, experimental, or field techniques used to investigate them; the limitations of current geological techniques and geological controversies; and great geological expeditions, experiments, and studies from the past, their premises, and their results. Students taking graduate version complete additional assignments.
EAPS Staff

12.471 Essentials of Geobiology
Prereq: None
G (Fall)
Not offered regularly; consult department
3-4-5 units

Introduces basic concepts of microbial structure, growth, energetics, molecular biology, and biochemistry. Presents examples of microbial interactions with environments throughout Earth's history as well as current topics in astrobiology. Includes lectures, discussions of literature, and a field trip. Lab focuses on student-designed projects that involve cultivation, modeling, or sample analyses. Intended for students whose background is not in biology, but who want to learn more about the contribution of microbes to geochemistry and planetary evolution.
T. Bosak

12.473 Paleomagnetism and Planetary Magnetism
Prereq: (12.002 and 18.03) or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
2-0-4 units

Introduces the study of natural remanent magnetization and the generation of planetary magnetic fields. Topics include paleomagnetism, rock magnetism, geomagnetism, magnetostratigraphy, paleomagnetic measurement techniques, polar wander and continental drift, biomagnetism, dynamo theory, and the history and evolution of magnetic fields on the Earth and planets.
B. P. Weiss

12.474 Origin and Evolution of the Earth's Crust
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-6 units

Broad overview of the origin and evolution of Earth's crust and mantle with emphasis on the study of the Precambrian rock record. Topics include: processes of crustal growth, stabilization, and reactivation; evaluation of secular change; and use of radiogenic isotopes in geochronology and as tracers of crust forming processes.
O. Jagoutz

12.475 Plate Tectonics and Climate
Subject meets with 12.100
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-6 units

Explores plate tectonics and the fundamental relationship between tectonic systems and global climate. Provides an in-depth study of plate tectonics, encompassing sea floor spreading, continental rifting, mountain and basin formation, and subduction. Examines the profound effects of tectonic activity on global climate, emphasizing the critical links between solid earth processes and long-term climate change and offering a holistic view of our planet's intricate systems. Regional case studies present examples of the complex interconnections along Earth's long history. An optional weekend field trip brings concepts encountered in class into a tangible, real-world context. Expectations differ for students taking graduate version.
O. Jagoutz, L. H. Royden, K. Bergmann

12.476 Radiogenic Isotope Geology
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-3-6 units

Applications of the variations in the relative abundance of radiogenic isotopes to problems of petrology, geochemistry, and tectonics. Topics: geochronology; isotopic evolution of Earth's crust and mantle; petrogenesis; and analytical techniques.
EAPS Staff

12.477 Astrobiology, Origins and Early Evolution of Life
Subject meets with 12.177
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Provides an understanding of major areas of research into the problem of the origin of life on the early Earth from an astrobiological perspective. Topics include the timing, setting and conditions for the origin of life on the Hadean Earth; roles of planetary and extra-planetary processes; defining life; prebiotic chemistry; origins of nucleic acids and peptides; evolution of cellularity, replication, metabolism, and translation; establishment of the genetic code; biogenesis vs. ecogenesis; the nature of the last common ancestor of life; conceptualizing the "tree of life;" and the early evolution of the ancestors of bacteria, archaeal, and eukaryal lineages. Students taking graduate version complete an extra project.
G. Fournier

12.478 The Phylogenomic Planetary Record
Subject meets with 12.178
Prereq: None
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units

Introduces the tools of sequence-based phylogenetic analysis and molecular evolution in the context of studying events in Earth's deep past that have been preserved by genomes. Topics include basic concepts of cladistics, phylogeny and sequence evolution, construction of phylogenetic trees of genes and microbial lineages, molecular clocks, dating, and ancestral sequence reconstruction. Special attention to the evolutionary history of microbial metabolisms and their relationship to global biogeochemical cycles across Earth's history. Students taking graduate version complete additional assignments.
G. Fournier

12.480 Thermodynamics for Geoscientists
Prereq: 3.046 or 5.60
G (Spring)
Not offered regularly; consult department
3-0-9 units

Principles of thermodynamics are used to infer the physical conditions of formation and modification of igneous and metamorphic rocks. Includes phase equilibria of homogeneous and heterogeneous systems and thermodynamic modelling of non-ideal crystalline solutions. Surveys the processes that lead to the formation of metamorphic and igneous rocks in the major tectonic environments in the Earth's crust and mantle.
T. L. Grove

12.481 Advanced Field Geology I
Prereq: 12.113
G (Fall)
Not offered regularly; consult department
2-2-2 units
Can be repeated for credit.

Introduction to the problems to be investigated in 12.482, as well as the regional setting and local geology of the field area. Various special techniques may be introduced and preparatory investigations may be conducted that are specific to the area to be studied in 12.482.
O. Jagoutz

12.482 Advanced Field Geology II
Prereq: 12.481
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (IAP)
Units arranged
Can be repeated for credit.

In January, a geological and geomorphological study of a selected field area is conducted during a two-week excursion. Exercises include geological and geomorphological mapping on topographic and photographic base maps of a wide variety of bedrock and surficial rocks. Where feasible, geochemical and geophysical field measurements are correlated with geology. Meets with 12.115 when offered concurrently.
O. E. Jagoutz

12.487A Field Geobiology I
Subject meets with 12.117A
Prereq: Permission of instructor
G (Spring; first half of term)
Not offered regularly; consult department
2-1-3 units

Examines basic biological processes that operate in sediments. Lectures cover biological, physical and chemical processes that influence the formation and stabilization of sediments, including biomineralization, weathering, erosion, the formation of sedimentary structures and interactions with sediments, flow, and the cycles of nutrients. Lab covers analytical methods used to examine microbial processes, bioinformatic methods used to analyze microbial communities, and techniques used to analyze sediment grain sizes and chemistry. Readings and discussions provide preparation for the 12.487B field trip to a modern sedimentary environment. Enables students to interpret processes in modern sedimentary environments, reconstruct similar processes in the rock record, collect appropriate samples in the field, and analyze microbiological data. Students taking graduate version complete additional assignments.
T. Bosak

12.487B Field Geobiology II
Subject meets with 12.117B
Prereq: Permission of instructor
G (Spring; second half of term)
Not offered regularly; consult department
2-2-5 units

Teaches fundamentals of field observations and reasoning in geobiology/sedimentology during a required trip to a modern sedimentary environment over spring break, followed by laboratory analyses of collected samples. Students make observations, develop hypotheses, collect samples required to test their hypotheses and interact with lecturers and students investigating the sedimentology of the site. Upon return to MIT, students work on field samples to characterize the sediments, use the preliminary data to develop an understanding of the field site, and write research reports. Students taking graduate version write proposals that present a research question based on the field observations and subsequent analyses. Meets with 12.110B and 12.465B when those subjects examine modern sedimentary environments.
T. Bosak

12.493[J] Microbial Genetics and Evolution
Same subject as 1.87[J], 7.493[J], 20.446[J]
Prereq: 7.03, 7.05, or permission of instructor
G (Fall)
4-0-8 units

See description under subject 7.493[J].
A. D. Grossman, O. Cordero

12.494 Geochemistry of Natural Waters
Subject meets with 12.104
Prereq: Calculus II (GIR)
G (Spring)
3-2-7 units

Equips students with the fundamental skills to identify major controls on the chemistry of waters on the Earth. Students examine key concepts, theories and practical tools (e.g., pH, Eh, alkalinity, surface charge, speciation, and carbonate equilibrium) and apply them as tools to understand and make predictions for the biogeochemical cycles of the Earth systems. Graduate students complete additional assignments.
S. Ono

Geophysics

12.501 Essentials of Global Geophysics
Subject meets with 12.201
Prereq: Physics II (GIR) and 18.03
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
4-0-8 units

Overview of basic topics in solid-earth geophysics, such as the Earth's rotation, gravity and magnetic field, seismology, and thermal structure. Formulation of physical principles presented in three one-hour lectures per week. Current applications discussed in an additional one-hour tutorial each week. Students taking graduate version complete different assignments.
R. van der Hilst

12.502 Flow, Deformation, and Fracture in Earth and Other Terrestrial Bodies
Subject meets with 12.202
Prereq: Calculus II (GIR) and Physics I (GIR)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-2-7 units

Covers fundamentals of deformation and fracture of solids and the flow of viscous fluids. Explores spatial scales from molecular to planetary, and time scales from fractions of a second to millions of years, to understand how and why natural materials on Earth and other terrestrial bodies respond to applied forces. Fundamental concepts include the principles of continuum mechanics, tensor representation of physical properties, forces, tractions, stresses, strain theory, elasticity, contact problems, fracture and friction, and viscous flow and rheological models (plasticity, viscosity, viscoelasticity, elasto-plasticity). Students gather, analyze and interpret data using existing theoretical models. Includes a significant laboratory component that provides practical experience with experimental measurements and tests students' acquired theoretical knowledge. Students taking graduate version complete different assignments.
B. Minchew, M. Pec

12.503 Mechanics of Earth
Subject meets with 12.203
Prereq: Calculus II (GIR) and Physics I (GIR)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-2-7 units

Covers topics in the deformation and fracture of solids and the flow of viscous fluids. Explores spatial scales from molecular to planetary, and time scales from fractions of a second to millions of years, to understand how and why natural materials on Earth and other terrestrial bodies respond to applied forces. Introduces anelasticity, granular mechanics, poroelasticity, rate-and-state friction, transport properties of Earth materials (Darcy's law, Fick's law), brittle-ductile transitions, creep of polycrystalline materials, stored energy and dissipation, and convection. Prepares students to gather, analyze and interpret data using existing theoretical models. Through a significant laboratory component, students obtain practical experience with experimental measurements and test their acquired theoretical knowledge. Students taking graduate version complete different assignments.
B. Minchew, M. Pec

12.507 Essentials of Field Geophysics
Subject meets with 12.214
Prereq: Physics II (GIR), 6.100A, and 18.03
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-3-6 units

Introduces students to the practical field application of various geophysical methods to studying Earth's to all aspects of near-surface and prepares students to undertake fieldwork that uses these methods. Methods covered include but are not limited to measuring seismic waves, gravity, precise positions (commonly referred to as GPS but formally known as GNSS), and topography using drones. Lab time involves local fieldwork to gain experience with the methods being taught. Students taking graduate version complete additional assignments.
B. Minchew, W. Frank

12.510 Introduction to Seismology
Subject meets with 12.210
Prereq: 18.075 or 18.085
G (Fall)
3-1-8 units

A basic study in seismology and the utilization of seismic waves for the study of Earth's interior. Introduces techniques necessary for understanding of elastic wave propagation in stratified media and for calculation of synthetic seismograms (WKBJ and mode summation). Ray theory; interpretation of travel times. (e.g., tomography); surface wave dispersion in layered media; Earth's free oscillations; and seismicity, (earthquake locations, magnitude, moment, and source properties). Students taking graduate version complete additional assignments.
W. Frank

12.511 Field Geophysics
Subject meets with 12.211
Prereq: 12.507 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (IAP; partial term)
1-4-1 units

Covers practical methods of modern geophysics, including the global positioning system (GPS), gravity, and magnetics. Field work is conducted in western US and includes intensive 10-day field exercise. Focuses on measurement techniques and their interpretation. Introduces the science of gravity, magnetics, and the GPS. Measures crustal structure, fault motions, tectonic deformations, and the local gravity and magnetic fields. Students perform high-precision measurements and participate in data analysis. Emphasizes principles of geophysical data collection and the relevance of these data for tectonic faulting, crustal structure, and the dynamics of the earthquake cycle. Students taking graduate version complete additional assignments.
W. Frank, B. Minchew, T. A. Herring

12.512 Field Geophysics Analysis
Subject meets with 12.212
Prereq: 12.511
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
2-0-4 units

Focuses on in-depth data analysis and development of skills needed to report results both in writing and orally. Students use data collected in 12.511 to develop written and oral reports of the results, with each student focusing on a different area. For example, students can develop the geophysical modeling or synthesis of the results into other studies in the area. The final written and oral reports are combined into a comprehensive report and presentation of the field camp and its results. Students taking graduate version complete additional assignments.
W. Frank, B. Minchew

12.515 Data and Models
Prereq: 18.075 or 18.085
G (Spring)
Not offered regularly; consult department
3-0-9 units

Surveys a number of methods of inverting data to obtain model parameter estimates. Topics include review of matrix theory and statistics, random and grid-search methods, linear and non-linear least squares, maximum-likelihood estimation, ridge regression, stochastic inversion, sequential estimation, singular value decomposition, solution of large systems, genetic and simulated annealing inversion, regularization, parameter error estimates, and solution uniqueness and resolution. Computer laboratory and algorithm development.
F. D. Morgan

12.521 Computational Geophysical Modeling
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Introduces theory, design, and practical methods of computational modeling in geodynamics and geophysical fluid dynamics. Covers the most effective and widely used numerical modeling approaches (e.g., boundary element, finite difference, finite element) and emphasizes problem-solving skills through illustrative examples of heat and mass transfer in the mantle and the ocean. Students acquire experience with various numerical methods through regularly assigned computational exercises and a term-long modeling project of each student's choice.
J. Lin, O. Marchal, M. Behn

12.522 Geological Fluid Mechanics
Prereq: 8.03 and (18.075 or 18.085)
G (Fall)
Not offered regularly; consult department
3-0-9 units

Treats heat transfer and fluid mechanics in the Earth, low Reynolds number flows, convection instability, double diffusion, Non-Newtonian flows, flow in porous media, and the interaction of flows with accreting and deforming boundaries. Applications include: the flow under plates, postglacial rebound, diapirism, magma dynamics, and the mantle convection problem.
J. A. Whitehead (WHOI)

12.525 Mechanisms of Faulting and Earthquakes
Subject meets with 12.225
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Explores the fundamental mechanics of faulting and earthquakes from four related perspectives: seismology, geodesy, geodynamics, and rheology. Topics to be covered include (1) the physical processes that control the rheology of faults, including friction and fracture, (2) how these rheological processes are manifest in faulting and earthquakes in the earth from a geodynamics perspective, and (3) how the mechanics of faulting and earthquakes are constrained by seismological and geodetic observations. Features both continental and oceanic examples of faulting and earthquakes. Students taking graduate version complete additional assignments.
C. Cattania

12.540 Principles of Global Positioning System
Prereq: Calculus II (GIR), Physics I (GIR), and 18.06
G (Spring)
3-0-9 units

The principles and applications of the Global Positioning System (US), GLONASS (Russia), Galileo (EU) and Beidou (China), known as Global Navigation Satellite Systems (GNSS), along with other space geodetic systems, including very-long-baseline interferometry (VLBI), satellite laser ranging (SLR), and Interferometric Synthetics Aperture Radar (InSAR). Topics covered include CDMA and FDMA encoding used by these systems to allow measurements of pseudo-range and carrier phase which allow millimeter accuracy positioning, models and analysis methods required for millimeter accuracy positioning. Other topics include: satellite orbit modeling, atmospheric refraction modeling, estimation techniques (including Kalman filtering), statistical and spectral analysis of data. Application areas include tectonic studies of Earth deformation, meteorology, space weather, and millimeter accuracy tracking of moving objects.
T. A. Herring

12.552 Advanced Seismology: Theory and Applications of Seismic Imaging
Prereq: 12.510
G (Spring)
Not offered regularly; consult department
3-0-9 units

Introduces fundamental principles of seismic imaging used in both exploration and solid earth applications. Topics include ray theoretical approaches, scattering theory, and seismic waveform modeling. Through lectures, projects and student-led discussions of journal articles, the class covers the whole process of seismic imaging, from data preprocessing to model generation and geological interpretation of the results.
EAPS Faculty

12.560-12.561 Advanced Seminar in Exploration Geophysics
Prereq: Permission of instructor
G (Fall, IAP, Spring)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.

Advanced seminar focusing on areas of current interest in exploration geophysics and seismology. 12.560 is letter-graded.
Geophysics Staff

12.570 Topical Issues in Global Geophysics
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Series of formal lectures and seminars with the specific content varying by term to reflect current issues in research. Meets jointly with relevant Harvard course.
R. D. van der Hilst

12.571 Seminar in Geophysics
Prereq: Permission of instructor
Acad Year 2024-2025: G (Fall, Spring)
Acad Year 2025-2026: Not offered
Units arranged [P/D/F]
Can be repeated for credit.

Problems of current interest in geophysics; subject matter varying from term to term.
Geophysics Staff

12.586 Modeling Environmental Complexity
Subject meets with 12.086
Prereq: 18.03 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Introduction to mathematical and physical models of environmental processes. Emphasis on the development of macroscopic continuum or statistical descriptions of complex microscopic dynamics. Problems of interest include: random walks and statistical geometry of landscapes; percolation theory and transport in disordered media; fractals, scaling, and universality; ecological dynamics and the structure of ecosystems, food webs, and other natural networks; kinetics of biogeochemical cycles. Appropriate for advanced undergraduates. Beginning graduate students are encouraged to register for 12.586. Students taking the graduate version complete different assignments.
D. H. Rothman

Planetary Science

12.601 Essentials of Planetary Science
Subject meets with 12.420
Prereq: (8.03, 12.002, and 18.03) or permission of instructor
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units

Reviews fundamental physical concepts pertaining to the study of the solar system, and highlights recent spacecraft results. Topics include: meteorites, orbital dynamics, asteroids, impact craters, surfaces, atmospheres, atmospheric dynamics, interiors, magnetospheres, rings, comets, formation of the solar system.
B. P. Weiss

12.603 Solar System Dynamics
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Studies the dynamics of the solar system and its major subsystems, and the dynamics of exoplanets, with a modern emphasis on the qualitative structure of phase space. Topics may include rotational dynamics, spin-orbit coupling, Cassini states, and orbital dynamics, resonances, and Kozai oscillations, tidal evolution and tidal heating.
J. Wisdom

12.612 Meteorites, Cosmochemistry, and Solar System Formation
Subject meets with 12.412
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

A broad introduction to cosmochemistry, the study of the solar system formation from a geochemical perspective. Examines how the current meteorite records are used to gain information on the processes that happened in the early solar system. Topics include the origin of elements and isotopes, chemical fractionations of them during different processes, meteorite records, pre-solar grains, cosmochemical models for the solar system formation, chronology of planetary bodies from radioactive isotopes, and analytical techniques commonly used in cosmochemistry. Students taking graduate version complete additional assignments.
N. X. Nie

12.620[J] Classical Mechanics: A Computational Approach
Same subject as 6.5160[J], 8.351[J]
Prereq: Physics I (GIR), 18.03, and permission of instructor
G (Fall)
3-3-6 units

Classical mechanics in a computational framework, Lagrangian formulation, action, variational principles, and Hamilton's principle. Conserved quantities, Hamiltonian formulation, surfaces of section, chaos, and Liouville's theorem. Poincaré integral invariants, Poincaré-Birkhoff and KAM theorems. Invariant curves and cantori. Nonlinear resonances, resonance overlap and transition to chaos. Symplectic integration. Adiabatic invariants. Applications to simple physical systems and solar system dynamics. Extensive use of computation to capture methods, for simulation, and for symbolic analysis. Programming experience required.
J. Wisdom, G. J. Sussman

12.621 Physical Principles of Remote Sensing
Subject meets with 12.421
Prereq: Physics II (GIR) and 6.100A
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Introduction to the physics of remote sensing with applications to the study of the Earth, Moon, planets and other solar system bodies, as well as to emerging fields, such as autonomous navigation. Includes the principles of optical, thermal, radar and lidar remote sensing. Covers fundamental properties of electromagnetic waves; principles of electromagnetic scattering from real and idealized materials, including various types of surfaces and vegetation; interaction of electromagnetic radiation with the atmosphere; and thermal and microwave emission from various media. Discusses past, present, and future remote sensing platforms along with the fundamentals of orbital mechanics and data processing tools and methods. Assignments require students to write simple computer programs and plot mathematical functions. Students taking graduate version complete different assignments.
B. Minchew

12.622 Planetary Atmospheres
Subject meets with 12.422
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Provides a basic understanding of the physics and chemistry of planetary atmospheres. Explores the formation and evolution of atmospheres, their structure and dynamics, and what is known about their chemical composition. Pays particular attention to their energy balance. Also presents the current state of understanding of exoplanet atmospheres. Students taking graduate version complete an additional research project.
J. de Wit

12.625 Extrasolar Planets: Physics and Detection Techniques
Subject meets with 8.290[J], 12.425[J]
Prereq: 8.03 and 18.03
G (Fall)
3-0-9 units

In-depth study of current topics in exoplanets, such as exoplanet transits, radial velocity curves, current survey missions, the mass-radius relation, and super Earths. Class activities consist of reading the current literature, problem sets, and a term project. Students taking graduate version complete additional assignments.
S. Seager

12.650 Current Topics in Planetary Science
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units
Can be repeated for credit.

In-depth discussion of current and classic literature on selected topics in planetary science. Topics vary from year to year.
J. Wisdom

12.652 Current Topics in Planetary Science
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

In-depth discussion of current and classic literature on selected topics in the specialty areas of asteroids and the Pluto-Charon system. Topics vary from year to year.
R. P. Binzel

Geological, Geophysical, and Chemical Oceanography

12.701 Classic Papers in Physical Oceanography
Prereq: None
G (Spring)
3-0-3 units

Provides a historical perspective on fundamental topics in oceanography by considering individual works which, when pieced together, contribute to the more cohesive description of how the ocean works. In class discussions, students consider various aspects of the work in question, including motivation, approach, and implications for the broader context. They also synthesize information and make oral presentations. Develops basic analytical and critical skills in paper reading and writing.
Y. Kwon (WHOI)

12.702 Elements of Modern Oceanography
Subject meets with 12.372
Prereq: None
G (Fall)
3-0-9 units

Examines a series of crosscutting topics that exemplify current directions in interdisciplinary oceanography. Focuses on current themes in oceanography, their interdisciplinary nature, and the role of ocean sciences in society. Introduces core concepts across the disciplines of biological, physical, and chemical oceanography as well as marine geology. Emphasizes the interdisciplinary aspects of these core concepts, the kinds of approaches and modes of thinking common to all of the disciplines, and the technological developments underpinning current advances. Students taking graduate version complete different assignments.
G. Lawson, A. Kirincich (WHOI)

12.703 Presenting Scientific Research
Prereq: None
G (Spring)
3-0-3 units

Presenting scientific research geared toward a scientific audience. Each student gives one 30-minute talk, one AGU-style 15-minute talk, and one poster presentation. Students present their ongoing research and use the class as a forum to practice for upcoming talks in more formal settings. Abstracts are prepared for each presentation and discussed in class. Students provide comments, questions, encouragement, critiques, etc. on their peers' presentations.
S. Nielsen, V. Le Roux (WHOI)

12.707 The History of Earth's Climate
Subject meets with 12.377
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Studies the climate history of the Earth, from the formation of the early atmosphere and ocean to the present. Evaluates geochemical, sedimentological, and paleontological evidence for changes in ocean circulation, global temperatures, and atmospheric carbon dioxide levels. Covers theories and models of Phanerozoic climate change. Provides a long-term history of the global carbon cycle. Students taking graduate version complete different assignments.
D. McGee

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

Seminar focusing on areas of current interest in paleoceanography and paleoclimatology. Includes discussion of current and classic literature. Topics vary from year to year.
D. Oppo, O. Marchal (WHOI)

12.710 Geological Oceanography
Prereq: Permission of instructor
G (Fall)
3-0-9 units

Provides a high level survey of a broad range of active science topics in Geological Oceanography. Presents background material that graduate students are expected to know in the disciplines of solid-earth geophysics, geochemistry, sedimentology and stratigraphy, coastal processes, and climate, including a representative set of canonical science papers, and builds on this material to give a sense of the current state of the science in these fields. Broad topics include the formation of the earth, petrogenesis, volcanism, plate tectonics, geodynamics, sedimentation in the oceans, coastal morphodynamics, paleo-oceanography, and climate. The interconnectedness of and feedbacks between processes discussed under these various topics is emphasized.
WHOI Staff

12.712 Advanced Marine Seismology
Prereq: Permission of instructor
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-0-6 units
Can be repeated for credit.

Focuses on synthetic seismograms, ocean bottom refraction seismology, and multi-channel reflection seismology as applied to studies of the ocean sediments, crust, and lithosphere. Topics include: the wave equations for elastic/anelastic, isotropic/anisotropic, homogeneous/heterogeneous and fluid/solid media; ray theory and WKBJ approximations; the Sommerfeld/Weyl integrals, asymptotic analysis, and Lamb's problem for a fluid/solid interface; reflectivity and related methods; finite difference and finite element methods; and special topics of interest to the class. Extensive readings of geophysical and seismological literature.
R. Stephen (WHOI)

12.714 Computational Data Analysis
Prereq: 18.03
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

An introduction to the theory and practice of analyzing discrete data such as are normally encountered in geophysics and geology. Emphasizes statistical aspects of data interpretation and the nonparametric discrete-time approach to spectral analysis. Topics include: elements of probability and statistics, statistical inference, robust and nonparametric statistics, the method of least squares, univariate and multivariate spectral analysis, digital filters, and aspects of multidimensional data analysis.
A. D. Chave, T. A. Herring

12.715 Environmental Bioinformatics
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

An intensive introduction to computational skills and a survey of modern computational theory and approaches for the manipulation and analysis of genomic data in environmental and non-model systems. Designed to synthesize theory (both biological and computational) and programming to equip students with the ability to understand and carry out hypothesis testing with genomic data. Topics include: introduction to programming and biological algorithms; genomic and transcriptomic data; environmental metagenomics; intraspecific diversity; and best practices in data science and reproducibility.
WHOI Staff

12.716 Essentials of Oceanic Petrology
Prereq: 12.710 or permission of instructor
G (Spring)
3-2-4 units
Can be repeated for credit.

Qualitative interpretation and quantitative analysis of melting, melt transport, melt-rock reactions, igneous crustal accretion, metamorphism and hydrothermalism at oceanic spreading centers and subduction-related arcs applied to understanding the variations in the composition of the Earth's (oceanic) mantle and crust and accretionalry processes at mid-ocean ridges. Combines theoretical methods with field, petrographic, geochemical, and computational techniques. Topics vary from year to year.
H. Dick, F. Klein (WHOI)

12.717 Coastal Geomorphology
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Explores mechanisms behind the formation and reshaping of coastal environments. Focuses on a process-based understanding of both the fluid dynamic and sediment transport aspects of coastal landforms, and, especially, the importance of feedbacks between the two. Investigates coastal evolution at various scales - from ripples to coastline formation - with an emphasis on the behavior of coastal environments over integrated timescales of days and years to centuries and millennia. Students investigate the effect of storms, sea-level rise, and interactions with biological and anthropogenic influences. Covers a broad array of coastal environments, including beaches, barrier islands, spits, inlets, tidal flats, deltas, rocky coasts, arctic shores, and carbonate atolls.
A. Ashton

12.718 Kinetics and Mass Transport
Prereq: Permission of instructor
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-0-6 units

Offers a broad overview of various kinetic and transport processes in geology, including volume and grain boundary solid-state diffusion, defects in minerals, rates of mineral reaction and transformation, crystal nucleation and growth, advective transport in porous media and partially molten aggregates, and percolation theory. Emphasis on processes in crystalline rocks. Covers theoretical, phenomenological, and experimental constraints, with a consistent application to "real-world" settings and actual case histories.
M. Behn and G. Gaetani (WHOI)

12.739 Marine Microbiology and Biogeochemistry
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Integrates the fields of microbiology and biogeochemistry, and is centered on elucidating the linkages between microorganisms and geochemical processes in the oceans. Divided into modules that first lay the theoretical framework to familiarize students of diverse backgrounds (biologists, chemists, physical oceanographers). Next, introduces specific and general linkages between the topics and the major tools and techniques that have advanced their integrated study. Concludes with a synthesis module examining the role of microorganisms in the biogeochemical cycles of diverse ocean biomes
A. Apprill, S. Sievert (WHOI)

12.740 Paleoceanography
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Studies the basic principles of techniques for reconstructing the history of ocean climate from marine sediment cores, corals, ice cores, and other paleoclimate archives. Examines this data in the light of proposed climate change mechanisms. Micropaleontological, isotopic, geochemical, and mineralogical changes are used to infer changes in seawater composition, atmospheric chemistry, and climate. Observations are interpreted as consequences of changes in ocean temperature, circulation, and chemistry, and are used to evaluate theories proposed to account for glacial/interglacial cycles. Focuses on the past two million years, but major processes and events from the past 100 million years are also included.
E. A. Boyle

12.741 Marine Bioinorganic Chemistry
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
2-0-7 units

Provides an overview of trace element biogeochemistry and marine bioinorganic chemistry. Topics include controls on oceanic trace metal distributions; co-evolution of biological metal requirements and metal availability during early Earth history; chemical speciation and its influence on microbial bioavailability; applications of metal isotopes; roles of metalloenzymes and metal proteins in biogeochemical cycles; and biogeochemical applications of metagenomics, metaproteomics, and bioinformatics.
M. Saito

12.742 Marine Chemistry
Prereq: Permission of instructor
G (Fall)
3-0-9 units

An introduction to chemical oceanography. Reservoir models and residence time. Major ion composition of seawater. Inputs to and outputs from the ocean via rivers, the atmosphere, and the sea floor. Biogeochemical cycling within the oceanic water column and sediments, emphasizing the roles played by the formation, transport, and alteration of oceanic particles and the effects that these processes have on seawater composition. Cycles of carbon, nitrogen, phosphorus, oxygen, and sulfur. Uptake of anthropogenic carbon dioxide by the ocean. Material presented through lectures and student-led presentation and discussion of recent papers.
B. Van Mooy, E. Kojawinski (WHOI)

12.743 Geochemistry of Marine Sediments
Prereq: Chemistry (GIR) and 5.60
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Focuses on processes that control the composition of sediments in coastal, shelf, and deep-sea environments and processes that define their roles in biogeochemical cycles. Topics include calculating chemical fluxes across the sediment-water interface; evaluating the sources and reactivity of carbonate, silicic, and detrital sediments; using pore water gradients to calculate diffusion, reaction, and flux rates; sediment dating; estimating accumulation rates; and using stable isotopes and natural-series radioisotopes. Covers evaluation of the links between sedimentary and water column processes; the effects of anthropogenic disturbances (e.g., eutrophication, acidification, warming) on sedimentary processes; and the role of sediments in global biogeochemical cycles. Introduces sampling techniques and mathematical modeling of sedimentary processes.
D. McCorkle, W. Martin, A. Wang, M. Long (WHOI)

12.744 Marine Isotope Chemistry
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Fundamentals of using isotopes to study processes and timescales for marine chemistry and geochemistry. Provides basic introduction to the nature, origins, and reasons for the distributions of isotopes in nature, then develops theory and approaches for radioactive dating methods. These are used to constrain the timing and nature of the geochemical evolution of the elements, solar system, earth, ocean, and atmosphere. Covers cosmogenic isotopes and their applications. Briefly discusses basics of mass spectrometry, followed by a closer inspection of the principles and applications of isotope fractionation. Introduces mass independent fractionation and clumped isotope methods. Explores applications of isotope methods to a number of water column processes, including particle scavenging, sedimentation, long term element budgets, redox processes, and air-sea exchange. Emphasizes quantitative methods and problem-solving. Includes problem sessions with development of problem solutions.
WHOI Staff

12.746 Marine Organic Geochemistry
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-6 units

Provides an understanding of the distribution of organic carbon (OC) in marine sediments from a global and molecular-level perspective. Surveys the mineralization and preservation of OC in the water column and within anoxic and oxic marine sediments. Topics include: OC composition, reactivity and budgets within, and fluxes through, major reservoirs; microbial recycling pathways for OC; models for OC degradation and preservation; role of anoxia in OC burial; relationships between dissolved and particulate (sinking and suspended) OC; methods for characterization of sedimentary organic matter; application of biological markers as tools in oceanography. Both structural and isotopic aspects are covered.
D. Repeta (WHOI)

12.747 Modeling, Data Analysis, and Numerical Techniques for Geochemistry
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Emphasizes the basic skills needed for handling and assimilating data as well as the basic tool-set for numerical modeling. Uses MATLAB as its computation engine; begins with an introduction to MATLAB to ensure familiarity with software. Topics include: probability distributions, error propagation, least squares and regression techniques, principle component and factor analysis, objective mapping, Fourier and spectral analysis, numerical solutions to ODEs and PDEs, finite difference techniques, inverse models, and scientific visualization.
D. Nicholson (WHOI)

12.749 Solid Earth Geochemistry
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Integrates methods in mineralogy, petrology (both igneous and metamorphic), and trace element and isotope geochemistry to address scientific issues of the solid earth. Covers processes in the solar nebula, accretion, and early differentiation of the earth. Discusses topics in three representative geodynamic environments - mid-ocean ridges, subduction zones, and mantle plumes - with respect to physical framework and petrological/geochemical aspects.
N. Shimizu, S. Nielsen, G. Gaetani (WHOI)

12.751-12.759 Seminar in Oceanography at Woods Hole
Prereq: Permission of instructor
G (Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Topics in marine geology and geophysics, physical, dynamical, and chemical oceanography. Content varies from term to term. 12.754, 12.755, and 12.756 are letter-graded.
WHOI Staff

12.760-12.761 Seminar in Marine Geology and Geophysics at MIT
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Topics in marine geology and geophysics taught at MIT. Content varies from term to term. 12.760 is letter-graded.
Marine Geology and Geophysics Staff

12.770-12.771 Seminar in Chemical Oceanography at MIT
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Topics in chemical oceanography taught at MIT. Content varies from term to term. 12.770 is letter-graded.
Chemical Oceanography Staff

12.777 Field Oceanography
Subject meets with 12.373
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-7-5 units

Provides an introduction to the biogeochemistry of the ocean, and the field techniques and methods used in its study. Emphasizes biogeochemistry and the interrelated nature of elemental cycling, but also examines physical transport and air-sea gas exchange. Covers multiple aspects related to field instrumentation and measurements, including nutrients, oxygen, the carbon system, temperature, and salinity. Presents microbial analyses, such as metagenomics. Includes a mandatory spring break field trip aboard a research vessel; opportunities for funded travel available. Students work in groups to propose a project over the week-long voyage that utilizes the field time to collect samples. During the second half of the term, students analyze and synthesize the data, and present it in a publication-quality manuscript. Students taking graduate version complete additional assignments. Enrollment limited.
A. R. Babbin

Atmospheres, Oceans, and Climate

12.800 Fluid Dynamics of the Atmosphere and Ocean
Subject meets with 12.390
Prereq: 8.03 and 18.04
G (Fall)
3-0-9 units

Introduction to fluid dynamics. Students acquire an understanding of some of the basic concepts of fluid dynamics that are needed as a foundation for advanced coursework in atmospheric science, physical oceanography, ocean engineering, climate science, etc. Emphasizes fluid fundamentals, with an atmosphere/ocean twist. Students taking graduate version complete additional assignments.
A. Mahadevan, C. Cenedese

12.801 Large-scale Ocean Dynamics
Prereq: 12.800
G (Spring)
3-0-9 units

Applies fundamental principles of geophysical fluid dynamics to understand the general patterns of the ocean circulation and stratification. Includes the mid-latitude wind-driven circulation, the Southern Ocean circulation, and the global overturning circulation. Uses a combination of theory, numerical simulations, and observations to illustrate the concepts.
J. Yang (WHOI)

12.802 Waves, Instability and Turbulence at Small Scales
Prereq: 12.800 or permission of instructor
G (Spring)
3-0-9 units

Covers basic concepts of wave motion, flow instability, and turbulence in rotating and stratified fluids with emphasis on small scales. Presents wave properties, including the dispersion relation, phase and group velocities, and wave kinematics, and uses these concepts to study the dynamics of surface and internal gravity waves, Poincare waves, Kelvin waves, and topographic waves. Includes flow instability. Explores general concepts of linear instability in small-scale stratified shear flows (Rayleigh and Kelvin-Helmholtz instabilities); examines non-rotating stratified turbulence resulting from these instabilities. Also discusses wave-mean flow interaction, hydraulic control, the entrainment assumption, and the interpretation of microstructure observations.
G. Flierl, R. Ferrari

12.803 Advanced Geophysical Fluid Dynamics
Prereq: 12.843
G (Spring)
Not offered regularly; consult department
2-0-7 units

Further development of topics covered in 12.843, with a more mathematical treatment. Covers current topics of interest in rotating stratified flows of oceans and atmospheres.
G. Flierl, R. Ferrari

12.805 Data Analysis in Physical Oceanography
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Directed at making scientifically-sensible inferences from physical oceanography data (both observations and models). Introduces linear inverse methods, including regression, singular value decomposition, objective mapping, and data assimilation. Connects these methods to time series analysis, including Fourier methods, spectra, coherence, and filtering. Focuses on working with data in a computer laboratory setting. Emphasizes how statistical information can be used to improve experimental design. Gives some attention to the instruments and algorithms used to acquire the data.
G. Gebbie, T. Farrar (WHOI)

12.806[J] Atmospheric Physics and Chemistry
Same subject as 10.571[J]
Subject meets with 12.306
Prereq: (18.075 and (5.60 or 5.61)) or permission of instructor
G (Spring)
3-0-9 units

Introduction to the physics and chemistry of the atmosphere including experience with computer codes. Aerosols and theories of their formation, evolution, and removal. Gas and aerosol transport from urban to continental scales. Coupled models of radiation, transport, and chemistry. Solution of inverse problems to deduce emissions and removal rates. Emissions control technology and costs. Applications to air pollution and climate.
R. G. Prinn

12.807[J] Atmospheric Chemistry
Same subject as 1.84[J], 10.817[J]
Prereq: 5.601 and 5.602
G (Fall)
3-0-9 units

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

12.808 Introduction to Observational Physical Oceanography
Prereq: Permission of instructor
G (Fall)
3-0-9 units

Results and techniques of observations of the ocean in the context of its physical properties and dynamical constraints. Emphasis on large-scale steady circulation and the time-dependent processes that contribute to it. Includes the physical setting of the ocean, atmospheric forcing, application of conservation laws, description of wind-driven and thermohaline circulation, eddy processes, and interpretive techniques.
H. Seo, J. Toole (WHOI)

12.809 Hydraulic Phenomena in Geophysical Fluid Flows
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-6 units

Examination of the hydraulics of nonrotating flows (Long's experiments, hydraulic control, upstream influence, nonlinear wave steepening, hydraulic jump and bores, application to severe downslope winds). Other topics may include: nonrotating stratified flows (two-layer hydraulics, virtual and approach controls, maximal and submaximal flow, application to the Strait of Gibraltar and the Bab al Mandab); and deep ocean straits and sills (steady theories for rotating channel flow, nonlinear Kelvin and frontal waves, rotating hydraulic jumps, geostrophic adjustment in a rotating channel, and applications to the Denmark Strait and other deep passages).
L. Pratt, K. Helfrich (WHOI)

12.810 Dynamics of the Atmosphere
Prereq: 12.800
G (Spring)
3-0-9 units

Discusses the dynamics of the atmosphere, with emphasis on the large scale. Topics include internal gravity waves in the atmosphere; potential vorticity conservation and Rossby waves; baroclinic instability and extratropical storms; the tropical Hadley and Walker circulations and equatorial waves; and the general circulation, annular modes, and the response to climate change.
P. O'Gorman

12.811 Tropical Meteorology
Prereq: 12.810; or *Coreq: 12.843*
G (Spring)
Not offered regularly; consult department
3-0-9 units

A description of the large-scale circulation systems of the tropical atmosphere and analysis of the dynamics of such systems. Topics include: Radiative-convective equilibrium; the Hadley and walker circulation; monsoons; tropical boundary layers; theory of the response of the tropical atmosphere to localized sea-surface temperature anomalies; intraseasonal oscillations; equatorial waves; El Niño/Southern Oscillation; easterly waves; and tropical cyclones.
K. A. Emanuel

12.812 The General Circulation of the Atmosphere and Climate Change
Prereq: 12.810 or permission of instructor
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
2-0-7 units

Describes the general circulation of Earth's atmosphere and its maintenance. Second half of the course explores the response of the general circulation to climate change.
P. O'Gorman

12.814[J] Aerosol and Cloud Microphysics and Chemistry
Same subject as 1.842[J]
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units

Focuses on understanding how aerosol particles form droplets or ice crystals during several atmospheric processes: determining Earth's radiative balance; heterogeneous chemistry and acid rain; understanding where, when and how much precipitation occurs. Provides tools for understanding the physics of aerosol and cloud element motion; the interaction of particles with water vapor, including phase changes and droplet and ice nucleation; the chemical composition of particles and the effect on cloud formation processes; and the effect of cloud processing on aerosol chemistry. Discusses relevant topics of contemporary interest, e.g., geoengineering and weather modification and volcanic effects. Students taking the graduate version complete different assignments.
D. Cziczo

12.815 Atmospheric Radiation and Convection
Subject meets with 12.315
Prereq: 12.800 or permission of instructor
G (Spring)
3-0-9 units

Introduction to the physics of atmospheric radiation, remote sensing, and convection, including use of computer codes. Radiative transfer equation including emission and scattering, spectroscopy, Mie theory, and numerical solutions. Physics of dry and moist convection, including moist thermodynamics. Radiative-convective equilibrium. Solution of inverse problems in remote sensing of atmospheric temperature and composition. Students taking graduate version complete additional assignments.
T. Cronin

12.817[J] Atmospheric Composition and Global Change
Same subject as 1.841[J]
Prereq: 1.84[J]
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

See description under subject 1.841[J].
C. Heald

12.818 Introduction to Atmospheric Data and Large-scale Dynamics
Subject meets with 12.318
Prereq: None. *Coreq: 12.800*
G (Fall)
3-3-6 units

Provides a general introduction to meteorological data and analysis techniques, and their use in the MIT Synoptic Laboratory to study the phenomenology and dynamics of large-scale atmospheric flow. Illustrates balance concepts as applied to the dynamics of frontal and synoptic scales, using real-time upper-air and surface station data and gridded analyzed fields. Uses advanced meteorological software packages to access, manipulate, and graphically display the data. Students taking graduate version complete different assignments.
L. Illari

12.820 Turbulence in the Ocean and Atmosphere
Prereq: 12.843
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Covers phenomena, theory and modeling of turbulence in the Earth's oceans and atmosphere. The scope will range from centimeter- to planetary-scale motions. Includes homogeneous isotropic three- and two-dimensional turbulence, convection, stratified turbulence, quasi-gesotrophic turbulence, baroclinic turbulence, and macroturbulence in the ocean and atmosphere.
R. Ferrari, G. Flierl

12.823 Modeling the Biology and Physics of the Ocean
Prereq: 18.075 or 18.085
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-6 units

Principles and examples of the construction of physical/ biological models for oceanic systems. Individual-based and continuum representations. Food webs and structured population models. Fluid transport, stirring, and mixing. Effects of rotation and stratification. Advection, diffusion, reaction dynamics. Oceanic examples of physical-biological dynamics: surface mixed layer, upwelling regimes, mesoscale eddies, and oceanic gyres.
G. Flierl, D. McGillicuddy

12.824 Stability Theory for Oceanic & Atmospheric Flows
Prereq: 12.802 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Basic theory of hydrodynamic instability with special application to flows of interest in oceanography and meteorology. Topics covered include general formulation of stability theory; concept of normal modes and linearization; fundamental stability theorems; baroclinic instability: Charney model, Eady model and the Phillips two-layer model; energy transformations; initial value theory and non-modal instability; barotropic instability for jets and shear layers; radiating instabilities; initial value problems applied to the concepts of convective, absolute and spatial instabilities; finite amplitude theory; stability of non-parallel flows.
G. Flierl

12.830 Topics in Waves and Instability
Prereq: 12.843
G (Fall)
Not offered regularly; consult department
3-0-9 units

A detailed presentation of selected advanced topics in waves and instability in the atmosphere. The precise selection varies from year to year. Topics have included wave-mean flow interaction, the quasi-biennial oscillation, sudden warmings, critical-level behavior, wave overreflection, nonlinear equilibration, wave breaking, tropical waves, and stationary waves.
EAPS Staff

12.834[J] Land-Atmosphere Interactions
Same subject as 1.713[J]
Prereq: Permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

See description under subject 1.713[J].
D. Entekhabi

12.835 Experimental Atmospheric Chemistry
Subject meets with 12.335
Prereq: Permission of instructor
G (Fall)
2-4-6 units

Introduces the atmospheric chemistry involved in climate change, air pollution, and ozone depletion using a combination of interactive laboratory and field studies and simple computer models. Uses instruments for trace gas and aerosol measurements and methods for inferring fundamental information from these measurements. Students taking the graduate version complete different assignments.
R. Prinn, S. Ono

12.842 Climate Science
Subject meets with 12.301
Prereq: Chemistry (GIR), 18.03, or permission of instructor
G (Fall)
3-0-9 units

Introduction to climate studies, including beginnings of the solar system, time scales, and climate in human history; methods for detecting climate change, including proxies, ice cores, instrumental records, and time series analysis; physical and chemical processes in climate, including primordial atmosphere, ozone chemistry, carbon and oxygen cycles, and heat and water budgets; internal feedback mechanisms, including ice, aerosols, water vapor, clouds, and ocean circulation; climate forcing, including orbital variations, volcanism, plate tectonics, and solar variability; climate models and mechanisms of variability, including energy balance, coupled models, and global ocean and atmosphere models; and outstanding problems. Students taking the graduate version complete different assignments.
A. Fiore, P. O'Gorman

12.843 Large-scale Atmosphere and Ocean Dynamics
Prereq: 12.801, 12.810, or permission of instructor
G (Fall)
2-4-9 units

Project-based with lectures covering the relevant theory. Students work in groups on four projects. Each of these comprises a numerical part, to illuminate and illustrate the theory, and a data part (drawn from laboratory tank experiments, atmospheric, or ocean observations), to illustrate the phenomena. Topics include: barotropic vorticity dynamics including inversion and evolution, geostrophic and higher order balance, baroclinic dynamics and the evolution of balanced flows, and stability with emphasis on the mutual interaction of disturbances. Projects include a verbal presentation and writeup covering both the numerical and geophysical parts plus additional derivations as needed.
G. Flierl, L. Illari

12.845[J] Sustainability Science and Engineering
Same subject as IDS.526[J]
Prereq: None
G (Spring)
Not offered regularly; consult department
3-0-6 units

See description under subject IDS.526[J].
N. E. Selin

12.849 Mechanisms and Models of the Global Carbon Cycle
Subject meets with 12.349
Prereq: Permission of instructor
G (Spring)
3-0-9 units

Addresses changes in the ocean, terrestrial biosphere and rocks modulation of atmospheric carbon dioxide on timescales from months to millions of years. Includes feedbacks between carbon cycle and climate. Combines hands-on data analysis with the formulation of simple models rooted in basic physical, chemical and biological principles. Students create individual "toy" global carbon cycle models. Students taking graduate version complete different assignments.
M. Follows

12.850 Computational Ocean Modeling
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Numerical modeling in oceanography and environmental fluid mechanics. Focuses on the building of computational models that describe processes such as transport (advection, diffusion), reaction (ecosystems), and boundary forcing, of relevance in the ocean. Models are developed in a hierarchical manner, starting from the simple (zero-dimensional in space), and incrementally advancing toward more complex, time-evolving systems in one-, two- (shallow water) and three-dimensions (Primitive equations). Students build their own models using the finite volume approach with an appreciation and understanding of the working of general circulation models
A. Mahadevan (WHOI), W. Zhang (WHOI)

12.853 Advanced geophysical fluid dynamics
Prereq: 12.843 or permission of instructor
G (Fall)
Not offered regularly; consult department
2-0-7 units

Follow-on to 12.843, with a more mathematical treatment and extension of material to current topics of interest involving rotating, stratified flows of oceans and atmospheres.
G. Flierl

12.860 Climate Variability and Diagnostics
Prereq: Permission of instructor
G (Fall)
3-0-9 units

Explores climate variability and change, focusing on the atmosphere and ocean, while building experience applying diagnostic analyses to a range of modern observations and models. Provides practical insight, from regional to global scale, with applications to past and future climates. Emphasizes salient features of the mean climate system and modes of natural variability, as well as observed and projected manifestations of anthropogenic climate change. Students gain experience accessing, analyzing, and visualizing a wide range of gridded observational-based datasets, as well as output from global climate model simulations. Develops the tools necessary to apply climate diagnostic analysis to one's own research, as well as the interdisciplinary edge to critically assess and interpret the observational and model results underpinning the Fifth Assessment Reports of the Intergovernmental Panel on Climate Change.
C. Uhmmenhofer

12.862 Coastal Physical Oceanography
Prereq: 12.800
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units

Introduction to the dynamics of flow over the continental shelf, nearshore, and estuaries, emphasizing both theory and observations. Content varies somewhat according to student and staff interests. Possible topics include fronts, buoyant plumes, surface and bottom boundary layers, wind-driven upwelling, coastal-trapped waves, internal waves, quasi-steady flows, high-latitude shelf processes, tides, and shelf-open ocean interactions.
R. Todd, D. Ralston (WHOI)

12.863 Advanced Topics in Coastal Physical Oceanography
Prereq: 12.862 or permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-6 units

More specialized topics in the dynamics of flow over the continental shelf, including coastal-trapped waves, wind-driving, and mean flows. Emphasis on the relationship between theory and observations. Instrumentation and the application of statistical techniques also covered.
Woods Hole Staff

12.866 Theory of the General Circulation of the Ocean
Prereq: 12.800, 12.801, and 12.802
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

A review of wind-driven circulation, and the development of the baroclinic theory of the wind-driven circulation. Potential vorticity homohenization and the ventilated thermocline. Wind-driven circulation with continuous stratification, subduction/obduction. Equatorial thermocline and its relation to ENSO. Decadal climate variability. Thermohaline circulation and variability. Abyssal circulation. Mixing and energetics of the oceanic general circulation.
R. X. Huang (WHOI)

12.870 Air-Sea Interaction: Boundary Layers
Prereq: Graduate-level fluid mechanics and a subject on waves or permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Addresses the interaction of the atmosphere and ocean on temporal scales from seconds to days and spatial scales from centimeters to kilometers. Topics include the generation, propagation, and decay of surface waves; the processes by which mass, heat, momentum, and energy are transported vertically within the coupled atmospheric and oceanic boundary layers and across the air-sea interface; and the statistical tools, mathematical models, and observational methods that are used to quantify these processes.
R. Todd, D. Ralston (WHOI)

12.884[J] Dimensions of Geoengineering
Same subject as 1.850[J], 5.000[J], 10.600[J], 11.388[J], 15.036[J], 16.645[J]
Prereq: None
G (Fall; first half of term)
Not offered regularly; consult department
2-0-4 units

See description under subject 5.000[J]. Limited to 100.
J. Deutch, M. Zuber

12.885[J] Science, Politics, and Environmental Policy
Same subject as 11.373[J]
Subject meets with 12.385
Prereq: Permission of instructor
G (Fall)
3-0-6 units

Examines the role of science in US and international environmental policymaking. Surveys the methods by which scientists learn about the natural world; the treatment of science by experts, advocates, the media, and the public and the way science is used in legislative, administrative and judicial decision making. Through lectures, group discussions, and written essays, students develop a critical understanding of the role of science in environmental policy. Potential case studies include fisheries management, ozone depletion, global warming, smog, and endangered species. Students taking the graduate version complete different assignments.
S. Solomon, J. Knox-Hayes

12.900 EAPS First Year Graduate Seminar
Prereq: None
G (Fall)
4-0-2 units

Provides a shared experience for first-year graduate students in EAPS and the MIT/ WHOI Joint Program. Facilitates opportunities to interact with senior graduate students and to meet a wide range of faculty. Familiarizes students with departmental research within the themes of Earth, planets, climate, and life. Discusses resources, graduate life at MIT, and the path to PhD.
K. Bergmann, T. Cronin, J. de Wit, M. Pec

12.901 Proposals, Papers and Pathways
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
2-0-3 units

This seminar builds skills for writing scientific proposals and papers, and facilitates investigation of career pathways. Topics covered include scientific writing and graphics, peer review, proposal writing for grants and fellowships, and exploration of academic and non-academic careers.
P. O'Gorman

12.910 Communicating Ocean Science
Prereq: None
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall, Spring)
3-0-6 units

For students interested in improving their ability to teach science, the focus is on inquiry-based instructional methods and application to various audiences. Includes an opportunity to teach in a course at a local state university and in a supervised elementary school classroom. Class meets twice a week for 11 sessions, and episodically thereafter. The undergraduate lesson is arranged in consultation with Bridgewater State University faculty. Outreach in local school classrooms involves one session observing and three sessions teaching.
L. Mullineaux (WHOI), A. Michel (WHOI)

12.950, 12.951 Seminar in Physical Oceanography at MIT
Prereq: Permission of instructor
Acad Year 2024-2025: G (Fall, Spring)
Acad Year 2025-2026: Not offered
Units arranged [P/D/F]
Can be repeated for credit.

Topics in physical and dynamical oceanography. Content varying from term to term. 12.950 is letter-graded.
Physical Oceanography Staff

12.970, 12.971 Current Research in Earth, Atmospheric and Planetary Sciences
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations, laboratory work, or field work on Earth, atmospheric, or planetary issues. 12.970 is letter-graded.
EAPS Faculty

12.980, 12.981 Current Research in Joint Program at MIT
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations on problems in oceanography. 12.980 is letter-graded.
EAPS Staff

12.982, 12.983 Current Research in Joint Program at WHOI
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations, laboratory work, or fieldwork in oceanography. 12.982 is letter-graded.
WHOI Faculty

12.S488, 12.S489 Special Seminar in Structural Geology
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of structural geology not normally covered in regularly scheduled subjects. 12.S488 is letter-graded.
EAPS Staff

12.S490, 12.S491 Special Seminar in Geology and Geochemistry
Prereq: Permission of instructor
G (Spring; second half of term)
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of geology or geochemistry not normally covered in regularly scheduled subjects. 12.490 is letter-graded.
Geology and Geochemistry Staff

12.S492, 12.S493 Special Seminar in Geobiology
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of geobiology not normally covered in regularly scheduled subjects. 12.492 is letter-graded.
Geobiology Staff

12.S501 Special Seminar in Earth, Atmospheric, and Planetary Sciences
Prereq: None
G (Fall, Spring)
2-0-1 units
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of the earth sciences, planetary sciences, or astronomy not normally covered in regularly scheduled subjects. 12.592 is letter-graded.
EAPS Faculty

12.S590 Special Seminar in Geophysics
Prereq: Permission of instructor
Acad Year 2024-2025: G (IAP)
Acad Year 2025-2026: Not offered
Units arranged
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of geophysics not normally covered in regularly scheduled subjects.
T. Herring and V. Pankratius

12.S591 Special Seminar in Geophysics
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of geophysics not normally covered in regularly scheduled subjects. 12.S590 is letter-graded.
Consult EAPS Education Office

12.S592 Special Seminar in Earth, Atmospheric and Planetary Sciences
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of the earth sciences, planetary sciences, or astronomy not normally covered in regularly scheduled subjects.
EAPS Staff

12.S593 Special Seminar in Earth, Atmospheric and Planetary Sciences
Prereq: Permission of instructor
G (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of the earth sciences, planetary sciences, or astronomy not normally covered in regularly scheduled subjects. 12.592 is letter-graded.
EAPS Staff

12.S594 Special Seminar in Earth, Atmospheric and Planetary Sciences
Prereq: None
G (Fall, IAP, Spring; second half of term)
Units arranged
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of the earth sciences, planetary sciences, or astronomy not normally covered in regularly scheduled subjects.
Consult EAPS Staff

12.S595 Special Seminar in Geophysics
Prereq: None
G (Fall)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of geophysics not normally covered in regularly scheduled subjects. 12.S590 is letter-graded.
EAPS Faculty

12.S596 Special Seminar in Earth, Atmospheric, and Planetary Sciences
Prereq: None
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of the earth sciences, planetary sciences, or astronomy not normally covered in regularly scheduled subjects.
EAPS Staff

12.S597 Special Seminar in Earth, Atmospheric and Planetary Sciences
Prereq: Permission of instructor
G (Fall, IAP)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of the earth sciences, planetary sciences, or astronomy not normally covered in regularly scheduled subjects. 12.592 is letter-graded.
EAPS Staff

12.S680, 12.S681 Special Seminar in Planetary Science
Prereq: Permission of instructor
G (Fall, Spring)
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of planetary science not normally covered in regularly scheduled subjects. 12.S680 is letter-graded.
Planetary Science Staff

12.S990, 12.S991 Special Subject in Atmospheric Science
Prereq: Permission of instructor
G (Fall, IAP, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of atmospheric science not normally covered in regularly scheduled subjects. 12.S990 is letter-graded.
PAOC Staff

12.S992, 12.S993 Special Subject in Climate Science
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of climate not normally covered in the regularly scheduled subjects. 12.S992 is letter-graded.
PAOC Staff