MIT/WHOI Joint Program in Oceanography/ Applied Ocean Science & Engineering

COURSE CATALOG

The following is a listing of Joint Program courses offered at WHOI and at MIT. This is not an exhaustive listing; students are encouraged to take other courses not listed here. Information regarding classes at MIT can be found online in the MIT course catalog at http://web.mit.edu/catalogue/subje.bycou.shtml.

Each course is assigned a course number. Courses starting with a 1. are in the area of civil and environmental engineering; those beginning with a 2. are in the area of ocean engineering; those starting with a 7. are in the area of biological oceanography; those starting with a 12. are in the area of earth and atmospheric sciences. They are all graduate-level courses.

Units are assigned to each course. Units are determined by adding the number of class hours, lab hours and expected homework hours per week.

WHOI has cross-registration agreements with other institutions including the Boston University Marine Program and Brown University.

Questions regarding courses, registration, and class schedules can be directed to the WHOI Registrar.

Last update: 6/20/07

2.681 Environmental Ocean Acoustics (12 units) Prereq: 18.075, 2.066 or permission of instructor
Fundamentals of underwater sound, and its application to mapping and surveillance in an ocean environment. Wave equations for fluid and elastic media. Reflection and transmission of sound at plane interfaces. Wave theory representation of acoustic source radiation and propagation in shallow and deep ocean waveguides. Interaction of underwater sound with elastic waves in the seabed and an Arctic ice cover, including effects of porosity and anisotropy. Numerical modeling of the propagation of underwater sound, including spectral methods, normal mode theory, and the parabolic equation method, for laterally homogeneous and inhomogeneous environments. Doppler effects. Effects of oceanographic variability and fluctuation - spatial and temporal coherence. Generation and propagation of ocean ambient noise. Modeling and simulation of signals and noise in traditional sonar systems, as well as modern, distributed, autonomous acoustic surveillance systems. *H. Schmidt (MIT)*

2.682 Acoustical Oceanography (12 units) Prereq: 2.681
Course will begin with brief overview of what important current research topics are in oceanography (physical, geological, and biological) and how acoustics can be used as a tool to address them. Three typical examples are climate, bottom geology, and marine mammal behavior. Will then address the acoustic inverse problem, reviewing inverse methods (linear and nonlinear) and the combination of acoustical methods with other measurements as an integrated system. Last part of course will concentrate on specific case studies, taken from current research journals. *J. Lynch*

2.683 Marine Bioacoustics and Geoacoustics (12 units) Prereq: 2.681
Both active and passive acoustic methods of measuring marine organisms, the seafloor, and their interactions are reviewed. Acoustic methods of detecting, observing, and quantifying marine biological organisms are described, as are acoustic methods of measuring geological properties of the seafloor, including depth, and surficial and volumetric composition. Interactions are also described, including effects of biological scatterers on geological measurements, and effects of seafloor scattering on measurements of biological scatterers on, in, or immediately above the seafloor. Methods of determining small-scale material properties of organisms and the seafloor are outlined. Operational methods are emphasized, and corresponding measurement theory is described. Case studies are used in illustration. Principles of acoustic-system calibration are elaborated. *K. Foote*

2.684 Wave Scattering by Rough Surfaces and Randomly Inhomogenous Media (12 units) Prereq: 2.066
An advanced-level subject designed to give the student working knowledge of current techniques in scattering and wave propagation through random media theory. Major application of theory presented is to ocean acoustics, but can be used in other acoustic and electromagnetic applications. Includes basics of wave propagation through random media theory, volume scattering by discrete scatterers (aerosols), scattering by rough surfaces, and acoustic propagation through ocean internal waves and mesoscale eddies. *T. Stanton, A. Lavery*

2.685 Numerical Methods in Wave Scattering (12 units) Prereq: 18.06 , 2.066
Fundamental equations for acoustic and electromagnetic waves are derived from first principles. Boundary, or interface, conditions are introduced. The course emphasizes the development of numerical methods to solve wave equations in interior or exterior domains using boundary-element and finite-element techniques. Spectral techniques are also developed. A number of technical computational issues are addressed: discretization of geometry, order of approximation, efficiency, and analysis of numerical schemes. Validation is an essential exercise. Validation examples are drawn from analytical solutions for separable shapes. Applications of numerical methods are presented for acoustic scattering by marine organisms of complex shape and structure, and optical scattering by dielectric bodies. Assignments will entail code development. *K. Foote, G. Feijoo*

2.686J Sonar, Radar, and Seismic Signal Processing (12 units) Prereq: 2.004 or 6.003; 6.041; 18.075 or 18.085
Signal processing used in sonar, radar, and geophysical data analysis. Active sonar and radar systems: matched filters and ambiguity functions, signal design of range/doppler resolution, second moment characterizations of random processes with correlation functions and power density spectra, deconvolution, spectral estimation by Fourier techniques and adaptive methods, beam forming.
N. Makris (MIT), J. Preisig

2.687, 6.??? Time Series Analysis and System Identification (12 units) Prereq: 18.06, 6.003, and 6.431 (or equivalent courses within the ME department)
Matched filtering, power spectral estimation and adaptive signal processing and system identification algorithms are introduced. Algorithm development is framed as an optimization problem, and methods of finding both optimal and approximate solutions are described. Course includes an introduction to time-varying systems, first and second moment characterizations of stochastic processes, and state-space models. Algorithm derivation, performance analysis and robustness to modeling errors are covered for matched filter and power spectral estimation algorithms, stochastic gradient algorithms (LMS and its variants), Least Squares algorithms (RLS, order- recursive approaches), and the discrete-time Kalman Filter and its derivatives. Course includes laboratory exercises involving working with experimental data from a variety of fields, and a term paper/ project is required.
J. Preisig

2.688 Principles of Oceanographic Instrument Systems -- Sensors and Measurements (12 units) Prereq: 2.671, 18.075
Introduces theoretical and practical principles of design of oceanographic sensor systems. Transducer characteristics for acoustic, current, temperature, pressure, electric, magnetic, gravity, salinity, velocity, heat flow, and optical devices. Limitations on these devices imposed by ocean environment. Signal conditioning and recording; noise, sensitivity, and sampling limitations; standards. Principles of state-of-the-art systems being used in physical oceanography, geophysics, submersibles, acoustics discussed in lectures by experts in these areas. Day cruises in local waters during which the students will prepare, deploy and analyze observations from standard oceanographic instruments constitute the lab work for this subject. *M. Grosenbaugh, WHOI Staff*

2.689J Special Projects in Oceanographic Engineering (units arranged)
Special problems in oceanographic engineering, carried out under supervision of members of the staff of the Woods Hole Oceanographic Institution. Given at Woods Hole Oceanographic Institution. *WHOI Staff*

12.870 Air-Sea Interaction: Boundary Layers (9 units) Prereq: Permission of instructor
Examines the interaction of the atmosphere and ocean on time scales from minutes to months, with emphasis on effects within the near-surface boundary layers in both the air and water. Topics include the dynamics of the wave field and its role in mediating air-sea coupling, the scaling of surface layer turbulence, the effects of temperature stratification, and the mechanics of energy and momentum exchange across the interface. Methods for measuring and computing air/sea fluxes are reviewed. Modification of boundary layers by air/sea exchange, radiation, and turbulent mixing is treated using a hierarchy of boundary layer models made available for student use. *J. Trowbridge, E. Terray*

Biological Oceanography

7.410 Applied Statistics (12 units) Prereq: Permission of instructor
Applied statistics covers probability and distributions (normal binomial, poisson, exponential, lognormal and uniform), estimation and hypothesis testing, parametric and non-parametric one-sample and two-sample tests of means, analysis of variance for crossed and nested designs, linar and multiple regression with residual analysis, correlation and discrete data analysis using chi-squared tests. Discussion of experimental and sampling designs are included. Examples use data from biological studies. *V. Starczak*

7.411–7.419 Seminars in Biological Oceanography (units arranged)
Selected topics in biological oceanography. *Information: M. Neubert*

7.421 Special Problems in Biological Oceanography (units arranged)
Advanced problems in biological oceanography with assigned reading and consultation. *Information: M. Neubert*

7.430 – 7.431 Topics Courses Topics courses offered vary each term; some recent Topics courses include New Models for Demography and Dispersal, Marine Biological Acoustics, Regional Ecology, Marine Invertebrates of Cape Cod, Applied Marine Population Genetics, Microbial View of Iron (Fe), Symbiosis, Marine Mammal Toxicology, and Fisheries Oceanography.

7.430 Topics in Quantitative Marine Science (6 units) Prereq: Permission of instructor
Lectures and discussions on quantitative marine ecology. Topics vary from year to year.

7.431 Topics in Marine Ecology (6 units) Prereq: Permission of instructor
Lectures and discussions on ecological principles and processes in marine populations, communities, and ecosystems. Topics vary from year to year.

7.432 Topics in Marine Physiology and Biochemistry (6 units) Prereq: Permission of instructor
Lectures and discussions on physiological and biochemical processes in marine organisms. Topics vary from year to year.

7.433 Topics in Biological Oceanography (6 units) Prereq: Permission of instructor
Lectures and discussions on biological oceanography. Topics vary from year to year.

7.434 Topics in Zooplankton Biology (6 units) Prereq: Permission of Instructor
Lectures and discussions on the biology of marine zooplankton. Topics vary from year to year.

7.435 Topics in Benthic Biology (6 units) Prereq: Permission of instructor
Lectures and discussions on the biology of marine benthos. Topics vary from year to year.

7.436 Topics in Phytoplankton Biology (6 units) Prereq: Permission of instructor
Lectures and discussion on the biology of marine phytoplankton. Topics vary from year to year.

7.437 Topics in Molecular Biological Oceanography (6 units) Prereq: Permission of instructor
Lectures and discussion on molecular biological oceanography. Topics vary from year to year.

7.438 Topics in the Behavior of Marine Animals (6 units) Prereq: Permission of instructor
Lectures and discussion on the behavioral biology of marine animals. Topics vary from year to year.

7.439 Topics in Marine Microbiology (6 units) Prereq: Permission of instructor
Lectures and discussion on the biology of marine prokaryotes. Topics vary from year to year.

7.440 An Introduction to Mathematical Ecology (9 units) Prereq: 18.01, 1.018 or permission of instructor)
Covers the basic models of population growth, demography, population interaction (competition, predation, mutualism), food webs, harvesting, and infectious disease, and the mathematical tools required for their analysis. Because these tools are also basic to the analysis of models in biochemistry, physiology, and behavior, subject also broadly relevant to students whose interests are not limited to ecological problems. *M. Neubert, H. Caswell*

7.47 Biological Oceanography (12 units)
Intensive overview of biological oceanography. Major paradigms discussed, and dependence of biological processes in the ocean on physical and chemical aspects of the environment examined. Surveys the diversity of marine habitats, major groups of taxa inhabiting those habitats, and the general biology of the various taxa: the production and consumption of organic material in the ocean, as well as factors controlling those processes. Species diversity, structure of marine food webs, and the flow of energy within different marine habitats detailed and contrasted.
S. Beaulieu, S. Sievert

7.491 Research in Biological Oceanography (units arranged)
Directed research in biological oceanography not leading to graduate thesis and generally done before the qualifying examination. Possible areas include population dynamics, physiology, and cytology of marine microorganisms; physiology, nutrition, and productivity of phytoplankton; influence of organisms on the composition of seawater; systematics, physiology, and ecology of pelagic larvae, zooplankton, benthos, and mesopelagic fishes; physiology and migration of large fishes; diving physiology; and use of sound by marine mammals. *WHOI Staff*

7.50 Method and Logic in Molecular Biology (12 units) Prereq: 7.51 and 7.52 or permission of instructor
Logic and experimental design: an in-depth discussion and assessment of biochemical, physical, and genetic methods employed in testing hypotheses. Limited to Course VII graduate students.
A. Amon, P. Garrity, L. Guarente, D. Housman, R. O. Hynes, S. Lindquist (MIT)

7.51 Principles of Biochemical Analysis (12 units) Prereq: Permission of instructor
Fundamental principles of biochemistry. Analysis of the structure and mechanism of catalytic and regulatory macromolecules. *T. Baker, R. T. Sauer, F. Solomon (MIT)*

7.52 Genetics for Graduate Students (12 units) Prereq: Permission of instructor
Principles and approaches of genetic analysis, including Mendelian inheritance and prokaryotic genetics, developmental genetics, neurogenetics, population genetics, human genetics, genomics, and epigenetics. Recitations and problem sets supplement lectures. *H. R. Horvitz, C. Kaiser (MIT)*

Geophysics

12.522 Geological Fluid Mechanics (12 units) Prereq: 8.03; 18.076 or 18.085
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. Whitehead

12.525 Mechanisms of Faulting and Earthquakes (12 units) Prereq: Permission of instructor
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. Both continental and oceanic examples of faulting and earthquakes will be featured. *J. Lin, J. McGuire*

Geological, Geophysical, and Chemical Oceanography

1.76 Aquatic Chemistry (12 units) Prereq: 5.11 or 5.111 or 5.112 or 5.60
Quantitative treatment of chemical processes in aquatic systems such as lakes, oceans, rivers, estuaries, groundwaters, and wastewaters. A brief review of chemical thermodynamics is followed by discussion of acid-base, precipitation-dissolution, coordination, and reduction-oxidation reactions. Emphasis is on equilibrium calculations as a tool for understanding the variables that govern the chemical composition of aquatic systems and the fate of inorganic pollutants. *J. Seewald*

1.83 Environmental Organic Chemistry (12 units) Prereq: 5.12, 5.60
Focuses on the processes affecting anthropogenic organic compounds in the environment. Uses physical chemical properties to predict chemical transfers between environmental compartments (air, water, sediments, and biota). Uses molecular structure-reactivity relationships to estimate chemical, photochemical, and biochemical transformation rates. Resulting process models are combined to predict environmental concentrations (and related biological exposures) of hazardous and natural organic compounds. *P. M. Gschwend (MIT)*

12.707 Pre-Pleistocene Paleoceanography and Paleoclimatology (12 units) Prereq: Permission of instructor
Climate history of the Earth from the formation of the early atmosphere and ocean to the present. Evaluation of geochemical, sedimentological, and paleontological evidence for changes in ocean circulation, global temperatures, and atmospheric carbon dioxide levels. Theories and models of Phanerozoic climate change. Long-term history of the global carbon cycle. *WHOI Staff*

12.708 Special Topics in Paleoclimatology (Units arranged) Prereq: Permission of instructor
Advanced 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, J. McManus*

12.710 Marine Geology and Geophysics I (12 units)
An introduction to marine geology and geophysics suitable for any student interested in the ocean sciences. Also intended as part of a two-semester sequence for first-year MIT-WHOI Joint Program students in marine geology and geophysics (MG&G). Topics include: deposition and preservation of marine sediments, climate proxies, Cenozoic to Holocene climate history, paleoceanography, marine stratigraphy and geochronology, structure of the earth, structure of oceanic crust, evolution of the oceanic lithosphere, mantle geodynamics, plate tectonics, ocean altimetry, and coastal sediment processes. *J. McManus, K. Sims, W. Zhu*

12.711 Marine Geology and Geophysics II (12 units)
An introduction to marine geology and geophysics intended as part of a two-semester sequence for first-year MIT-WHOI Joint Program students in marine geology and geophysics. Topics include: lithosphere evolution and mantle dynamics, the structure and composition of the oceanic crust and mantle, tectonic and magmatic processes at mid-ocean ridges, hotspot volcanism, subduction and arc magmatism, and the crustal structure and sedimentation history of continental margins. *N. Shimizu, S. Humphris, D. Smith*

12.712 Advanced Marine Seismology (12 units) Prereq: 12.710, 12.711
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. *WHOI Staff*

12.714 Computational Data Analysis (12 units) Prereq: 18.03
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. Chave*

12.716 Igneous Processes at Oceanic Margins (9 units) Prereq: 12.710, 12.711 or permission of instructor
Quantitative analysis of melting, melt transport, and igneous crustal accretion at oceanic spreading centers, rifted continental margins, and subduction-related arcs, applied to understanding variation in composition and volume of the Earth's crust in different tectonic environments. Theoretical methods for calculation of melt volume and composition, solid-liquid equilibria and reaction rates, and liquid density and viscosity combined with field, petrographic, geochemical, and computational techniques. Topics vary from year to year. *H. Dick, G. Gaetani*

12.718 Kinetics and Mass Transport (9 units) Prereq: Permission of instructor
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. *WHOI staff*

12.721 Special Problems in Marine Geology and Geophysics at Woods Hole (units arranged)
For graduate students desiring to perform special investigations, special laboratory work, or special fieldwork in marine geology and geophysics. *WHOI Staff*

12.722 Special Problems in Chemical Oceanography at Woods Hole (units arranged)
For graduate students desiring to perform special investigations, special laboratory work, or special fieldwork in chemical oceanography. *WHOI Staff*

12.740 Paleoceanography (12 units) Prereq: Permission of instructor
The history of the earth-surface environment is deduced from the records preserved in deep-sea sediments, ice cores, and corals. Micropaleontological, isotopic, geochemical, and mineralogical changes are used to infer changes in seawater composition, atmospheric chemistry, and climate. These observations are interpreted as consequences of changes in ocean temperature, circulation, and chemistry and used to evaluate theories proposed to account for glacial/interglacial cycles (e.g. orbital forcing). The past 2 million years are emphasized, but major processes and events from the past 100 million years are included. *E. A. Boyle (MIT)*

12.742 Marine Chemistry (12 units) Prereq: Permission of instructor
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.
S. Doney

12.743 Geochemistry of Marine Sediments (12 units) Prereq: 5.11 or 5.111 or 5.112 or 3.091; 5.60
Factors influencing the composition of deep-sea sediments and their spatial and temporal variability. Carbonate, silicic, organic, and detrital phases: sources and reactivity. Pore water: diffusion, reaction, and chemical fluxes across the sediment-water interface. Sediment dating and accumulation rate and mixing rate estimates. Stable isotopes, natural-series radioisotopes, and trace elements. Effect of climate change on sedimentary processes. Mathematical techniques and modeling in sedimentary systems. *D. McCorkle, W. Martin*

12.744 Marine Isotope Chemistry (6 units – half-term course with 12.748)
Focuses on isotope systematics applied to important problems in marine chemistry, specifically isotope systematics of light stable isotopes and intermediate mass stable isotope systematics.
WHOI staff

12.745 Ore Deposition at Submarine Ridge Axes (9 units) Prereq: Permission of instructor
Ridge crest hot springs; and description of currently active systems. Geologic and tectonic setting and exploration strategies. Hydrothermal chemistry of sediment-starved and sediment-covered spreading centers and seamounts. Thermodynamic modeling of water-rock interactions using EQ3/6. Description and classification of ore deposits formed on the sea floor. Chemical and physical mechanisms of ore localization. Formation of metalliferous sediments. *MIT Staff*

12.746 Marine Organic Geochemistry (9 units) Prereq: Permission of instructor
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, T. Eglinton*

12.747 Modeling, Data Analysis, and Numerical Techniques for Geochemistry (12 units)
Prereq: Permission of instructor
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. Glover, W. Jenkins, S. Doney*

12.748 Introduction to Isotope Chemistry (6 units – half-term course with 12.744 or 12.749)
Teaches fundamental aspects of isotope chemistry applied to the ongoing evolution of Earth and its major geochemical reservoirs (core, mantle, oceanic and continental crusts, seawater) in the context of solar system evolution. The course introduces students to nuclear physics, nucleosynthesis, mass spectrometry, isotope fractionation processes and the application of important isotope groups to fundamental processes in Earth's chemical evolution. *WHOI Staff*

12.749 Solid Earth Geochemistry (6 units – half-term course with 12.748)
Uses the isotopic methods and tools developed in 12.748, in conjunction with major and trace element systematics to examine in detail the fundamental processes of solid Earth accretion and differentiation. Introduces concepts of nebular condensation, meteorites and their parent bodies, origin and evolution of the moon, planetary differentiation, formation and evolution of the Earth's mantle and crust, and magmatism in ocean basins. *WHOI Staff*

12.751–12.759 Seminar in Oceanography at Woods Hole (Units arranged)
Topics in marine geology and geophysics, physical, dynamical, and chemical oceanography. Content varies from term to term; some recent seminars offered include Advanced Marine Geophysics, Classic Papers in Physical Oceanography, Computational Geodynamics Modeling, Marine Chemistry Seminar, Marine Geodynamics Seminar, Earthquake Siesmology, Oceanic Faulting and Earthquakes, Science and Communication, Student Seminar in Geology & Geophysics, Active Source Marine Seismology, Advanced Marine Geophysics, The Arctic System: An Interdisciplinary Approach, and Trace Metal Biogeochemistry. 12.754, 12.755 and 12.756 are letter-graded. *WHOI Staff*

12.751–12.759 Seminar in Oceanography at Woods Hole (Units arranged)
Topics in marine geology and geophysics, physical, dynamical, and chemical oceanography. Content varies from term to term; some recent seminars offered include Advanced Marine Geophysics, Classic Papers in Physical Oceanography, Computational Geodynamics Modeling, Marine Chemistry Seminar, Marine Geodynamics Seminar, Earthquake Siesmology, Oceanic Faulting and Earthquakes, Science and Communication, Student Seminar in Geology & Geophysics, Active Source Marine Seismology, Advanced Marine Geophysics, The Arctic System: An Interdisciplinary Approach, and Trace Metal Biogeochemistry. 12.754, 12.755 and 12.756 are letter-graded. *WHOI Staff*

12.800 Fluid Dynamics of the Atmosphere and Ocean (12 units) Prereq: 8.03, 18.04
Introductory subject for first-year graduate students in meteorology, climate, and oceanography. Eulerian and Lagrangian kinematics. Equations of mass, momentum, and energy in Eulerian form in rotating frame of reference. Vorticity and divergence. Scaling and geostrophic approximation. Potential vorticity. Ekman layers. Vortex motion. *J. Pedlosky*

12.801 Steady Circulation of the Oceans (12 units) Prereq: 12.800
Fundamental principles in modeling steady flows in the ocean and their analogues in the atmosphere. Illustrates general methods that apply to either fluid and the contrasts between them. Includes quasi-geostrophy on the beta plane and planetary geostrophy on the sphere, Ekman pumping, wind- and thermally driven ocean circulation models, western-boundary current dynamics, and abyssal circulation. *K. Helfrich*

12.802 Wave Motions in the Ocean and Atmosphere (12 units) Prereq: 12.800
Basic ideas of geophysical wave motion in rotating, stratified, and rotating-stratified fluids. Subject begins with general wave concepts of phase and group velocity. The dynamics and kinematics of gravity waves with a focus on dispersion, energy flux, initial value problems, etc. Subject foundation used to study internal and inertial waves, Kelvin, Poincare, and Rossby waves in homogeneous and stratified fluids. Laplace tidal equations are applied to equatorial waves. Other topics include: resonant interactions, potential vorticity, wave-mean flow interactions, and instability. *P. Rizzoli (MIT)*

12.803 Quasi-balanced Circulations in Oceans and Atmospheres (12 units) Prereq: 12.800, [12.804]
Dynamics of large-scale circulations in oceans and atmospheres, taken concurrently with the laboratory subject 12.804. Basic concepts include mass and momentum conservation, hydrostatic and geostrophic balance, and pressure and other vertical coordinates. Barotropic vorticity equation: potential vorticity (PV) and invertibility; Greens functions/point vortices; balance in forced flow, waves, and vortices. Shallow water equations, geostrophic adjustment. Stratified atmospheres and oceans: thermodynamics. The quasi-geostrophic (QG) equations, pseudo potential vorticity. Barotropic and baroclinic instabilities and the Rayleigh, Fjortoft and Chanrey-Stern theorems. Eady and Charney models. The superposition theorem and the continuous spectrum. Effects of boundary friction, upward wave radiation, and phase change of water. Frontogenesis and semigeostrophy. *K. A. Emanuel (MIT)*

12.804 Large-scale Flow Dynamics Laboratory (12 units) Prereq: 12.800, [12.803]
Laboratory component of subject 12.803. Analysis of observations of oceanic and atmospheric quasi-balanced flows, computational models, and rotating tank experiments. Illustrates the basic principles of potential vorticity conservation and inversion, Rossby wave propagation, baroclinic instability, and the behavior of isolated vortices. *L. Illari, G. Flierl (MIT)*

12.805 Laboratory in Physical Oceanography (9 units) Prereq: 12.808
An introduction to standard data analysis methods including time series analysis, objective mapping, empirical orthogonal functions, and dynamic analysis of hydrographic data. Emphasis on working with data in a computer laboratory setting using packaged software. Where appropriate, comparison is made with simple models. Some attention given to the instruments and algorithms used to acquire the data. *Staff*

12.808 Introduction to Observational Physical Oceanography (9 units) Prereq: Permission of instructor
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. *J. Price*

12.809 Hydraulic Phenomena in Geophysical Fluid Flows (9 units) Prereq: Permission of instructor
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*

12.820 Turbulence in Geophysical Systems (9 units) Prereq: 12.803
Introduction to turbulence in geophysical systems, including 3-dimensional, 2-dimensional, and quasi-geostrophic turbulence. Transition to turbulence through primary and secondary instabilities. Statistical theories of fully-developed turbulence. Influence of stratification and rotation. Parameterization of turbulent processes in ocean models. *R. Ferrari (MIT)*

12.822 Nonlinear Waves and Vortices: Turbulence in the Atmosphere & Ocean (9 units) Prereq: 18.305, 12.803
The dynamics of nonlinear waves in geophysical systems. Linear dispersion, nonlinear steepening, and solitary waves. Wave groups. Modulational instability. Particle motions in waves. Point vortices, vortex patches, and modons. Interactions between vortices and wave fields. Nonlinear instability, bifurcations, chaotic behavior. *G. Flierl (MIT), R. Schmitt (WHOI), R. Ferrari (MIT)*

12.824 Stability Theory for Oceanic & Atmospheric Flows (9 units) Prereq: Permission of instructor
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. *MIT or WHOI Staff*

12.862 Coastal Physical Oceanography (12 units) Prereq: 12.800
Introduction to the dynamics of flow over the continental shelf, 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.
S. Lentz, C. Cenedese, J. Lerczak

12.866 Theory of the General Circulation of the Ocean (12 units) Prereq: 12.800, 12.801, 12.802
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*

12.970–12.971 Special Problems in Physical Oceanography at Woods Hole (units arranged)
Reading, consultation, and original investigation on oceanographic problems. 12.970 is letter-graded.
WHOI Staff

Non-credit Summer Math Courses

Mathematical Methods for Engineers & Earth Sciences

The course is an introduction to the modern advanced mathematics used in many applications in engineering and applied science. It assumes familiarity with basic calculus and some linear algebra. The central topics are differential equations and matrix equations – the continuous and the discrete. In addition to the usual topics (Laplace Transform, Vector Calculus, Calculus of Variations, Complex Integration, Fourier Integrals, etc.), the course introduces Discrete Fourier Series, the Fast Fourier Transform, Difference Equations, the Finite Element Method, the z-Transform, and the Kalman Filter. *S. Tiwari*

Introductory Mathematics for Biologists

The goal is to teach biology majors the mathematical ideas used every day in research. The course stresses intuitive understanding rather than specific techniques. Students review the basic functional building blocks of applied mathematics in the context of dynamics. The course ultimately aims to teach a few essential skills that include describing a dynamical system, translating appropriate aspects into equations, and interpreting the results in terms of the original problem. *S. Tiwari*

Bioinformatics

This is an introductory course on Bioinformatics and the computational ideas behind it. It covers (in the opinions of many researchers) what every modern biologist ought to know about computer science. The focus is on a handful of algorithmic ideas that can be used to solve a large number of biological problems. The stress on ideas is important, and the course is therefore not a protocol-centered, practical approach to bioinformatics.

The course has no real prerequisites other than some healthy curiosity. Although we use MATLAB as our programming language, the course does not assume any prior familiarity with it, or indeed any programming language. Similarly, although the course targets biologists and assumes that they will have seen some molecular biology along the way, it nonetheless includes at least one introductory Molecular Biology lecture that covers the molecular biology relevant to the computational concepts in the course. *S. Tiwari*

Joint Program Course Schedules

Course #	Course Title	Units	Last Taught	Annual (1) Biannual (2)
	Applied Ocean Science & Engineering			
2.690	Ocean & Seabed Acoustics	12	SP 06	1
2.691	Wave Scattering by Rough Surfaces & Randomly Inhomogeneous Media	12	SP 07	2
2.693	Principles of Oceanographic Systems – Sensors & Measurements	12	SP 07	1
2.694J	Special Projects in Oceanographic Engineering	--		
12.870	Air-Sea Interaction: Boundary Layers	9	FA 05	2
1.ThG	Graduate Thesis (CEE)			
2.ThG	Graduate Thesis (ME)			
6.ThG	Graduate Thesis (EECS)			
	Biological Oceanography			
7.410	Applied Statistics	12	FA 06	2
7.411–19	Seminars in Biological Oceanography	6		
7.421	Special Problems in Biological Oceanography	--		
7.430	Topics in Quantitative Marine Science	6		
7.431	Topics in Marine Ecology	6		
7.432	Topics in Marine Physiology and Biochemistry	6		
7.433	Topics in Biological Oceanography	6		
7.434	Topics in Zooplankton Biology	6		
7.435	Topics in Benthic Biology	6		
7.436	Topics in Phytoplankton Biology	6		
7.437	Topics in Molecular Biological Oceanography	6		
7.438	Topics in the Behavior of Marine Animals	6		
7.439	Topics in Marine Microbiology	6		
7.440	An Introduction to Mathematical Ecology	9	SP 06	2
7.47	Biological Oceanography	12	SP 07	1
7.491	Research in Biological Oceanography	--		
7.ThG	Graduate Thesis (Biology)	--		
	Chemical Oceanography			
1.76	Aquatic Chemistry	12	FA 05	1
12.722	Special Problems in Chemical Oceanography	--		
12.740	Paleoceanography (MIT)	12		
12.741	Marine Geochemistry	12		
12.742	Marine Chemistry	12	FA 06	1
12.743	Geochemistry of Marine Sediments	12	SP 07	2
12.744	Marine Isotope Chemistry (1/2 term with 12.748)	6	FA 06	2
12.746	Marine Organic Geochemistry	9	SP 07	2
12.747	Modeling, Data Analysis & Numerical Techniques for Geochem.	12	FA 06	2
12.748	Intro. to Isotope Chemistry (1/2 term with 12.744 or 12.748)	6	FA 06	1
12.755	Trace Metal Biogeochemistry	6	SP 06	2
12.757	The Arctic System: An Interdisciplinary Approach	6	FA 07	
12.759	Marine Chemistry Seminar	6	SP 07	1
12.ThG	Graduate Thesis (EAPS)			

Joint Program Course Schedules

Course #	Course Title	Units	Last Taught	Annual (1) Biannual (2)
	Marine Geology & Geophysics			
12.521	Computational Geodynamics Modeling	9	SP 07	2
12.522	Geological Fluid Mechanics	12	FA 06	2
12.525	Mechanisms of Faulting & Earthquakes	12	FA 05	2
12.707	Pre-Pleistocene Paleoceanography & Paleoclimatology	12	SP 01	?
12.708	Special Topics in Paleoclimatology	9	FA 06	1
12.710	MG&G I (Introduction to MG&G)	12	FA 06	1
12.711	MG&G II (Chemical Geodynamics of Plate Boundaries & Mantle Plumes)	12	SP 07	1
12.712	Advanced Marine Seismology	9		
12.714	Computational Data Analysis	12	SP 06	2
12.716	Igneous Processes at Oceanic Margins	9	FA 05	2
12.718	Kinetics and Mass Transport	9	SP 06	2
12.721	Special Problems in MG&G	--		
12.749	Solid Earth Geochemistry (1/2 term with 12.748)	6	FA 05	2
12.751	Student Seminar in MG&G	--	FA 06	1
12.752	Oceanic Faulting & Earthquakes	6	FA 03	2
12.753	Marine Geodynamics Seminar	6	SP 07	1
12.754	Earthquake Seismology	6	SP 06	2
12.754	Active Source Marine Seismology	12	FA 06	?
12.755/56	Advanced Marine Geophysics	6	SP 07	2
12.ThG	Graduate Thesis (EAPS)	--		
	Physical Oceanography			
12.755	Hydraulic Phenomena in Geophysical Fluid Flows	6	FA 98	
12.757	Science & Communication	6	SP 05	2
12.758	Classic Papers in Physical Oceanography	6	SP 05	2
12.800	Fluid Dynamics of the Atmosphere & Ocean	12	FA 06	1
12.801	Steady Circulation of the Oceans (MIT)	12	SP 07	1
12.802	Wave Motions in the Ocean & Atmosphere (MIT)	12	SP 07	1
12.805	Laboratory in Physical Oceanography	9		
12.808	Introduction to Observational Physical Oceanography	9	FA 06	1
12.809	Hydraulic Phenomena in Geophysical Flows	9	FA 05	2
12.820	Turbulence in Geophysical Systems	9	SP 07	2
12.822	Nonlinear Waves & Vortices: Turbulence in the Atmosphere & Ocean	9	SP 05	2
12.824	Stability Theory for Oceanic & Atmospheric Flows	12	FA 04	2
12.862	Coastal Physical Oceanography	12	FA 06	2
12.866	Theory of the General Circulation of the Ocean	12	SP 06	2
12.950	Numerical Methods for Climate Dynamics	6	SP 07	2
12.971	Special Problems in Physical Oceanography	--		
12.ThG	Graduate Thesis (EAPS)			

ACADEMIC CALENDAR 2007 - 2008

2007

FALL TERM

65 Class Days (9/6-12/13): 12 Mondays, 13 Tuesdays, 15 Wednesdays, 13 Thursdays, 12 Fridays

September

3	Monday	Labor Day – Holiday
4	Tuesday	Registration Day – Fall term
5	Wednesday	First day of classes
7	Friday	Degree application deadline for February degrees
24	Monday	Student holiday – no classes
28	Friday	Cross-registration deadline

October

5	Friday	Add date – Last day to add subjects to registration
5	Friday	Last day to drop half-term subjects offered in 1st half
8,9	Monday, Tuesday	Columbus Day – Vacation (Joint Program students) – no classes
24	Wednesday	Half term subjects offered in the 2nd half of the term begin

November

12	Monday	Veterans' Day – Holiday
21	Wednesday	Last day to drop subjects from registration
21	Wednesday	Last day to add half-term subjects offered in 2nd half
22	Thursday	Thanksgiving Day – Holiday
23	Friday	Thanksgiving vacation (Joint Program students) – no classes

December

3	Monday	On-line preregistration for spring term begins
12	Wednesday	Last day of classes
14	Friday	Last day to submit or change advanced degree thesis title
14	Friday	Application deadline – EECS dept. applicants to Joint Program
18	Tuesday	Grade deadline
27	Thursday	Spring preregistration deadline

2008

January

7	Monday	First day of Independent Activities Period
11	Friday	Thesis due for doctoral degrees
15	Tuesday	Application deadline – Postdoctoral Programs and Joint Program
18	Friday	Last day to go off February degree list
18	Friday	Thesis due for engineers and masters degrees
21	Monday	Martin Luther King Jr. Day – Holiday

ACADEMIC CALENDAR 2007 - 2008

SPRING TERM

65 Class Days (2/5-5/15): 12 Mondays, 12 Tuesdays, 14 Wednesdays, 14 Thursdays, 13 Fridays

February		
1	Friday	Last day of Independent Activities Period
4	Monday	Registration Day – Spring Term
5	Tuesday	First day of classes
8	Friday	Degree application deadline for June degrees
15	Friday	Application deadline for Summer Student Fellow, Minority Fellow and Geophysical Fluid Dynamics Programs
18	Monday	Presidents' Day – Holiday
19	Tuesday	**Monday schedule of classes to be held**
March		
7	Friday	Add date – Last day to add subjects to registration
TBD		Joint Program Open House at WHOI and MIT
24-28	Monday-Friday	Spring Break (Joint Program students) – no classes or T/Th bus
April		
4	Friday	Last day to submit or change advanced degree thesis title
21,22	Monday, Tuesday	Patriots' Day – Vacation (Joint Program students) – no classes
24	Thursday	Drop date – Last day to cancel subjects form registration
May		
1	Thursday	On-line preregistration for summer & fall begins
2	Friday	Thesis due for doctoral degrees
9	Friday	Thesis due for engineers and masters degrees
15	Thursday	Last day of classes
20	Tuesday	Grade deadline
23	Friday	Last day to go off the June degree list
26	Monday	Memorial Day – Holiday
29	Thursday	Fall and summer preregistration deadline
June		
4	Wednesday	WHOI Graduate Reception – Clark 507
5	Thursday	MIT Doctoral Hooding Ceremony
6	Friday	MIT Commencement
9	Monday	Regular summer session begins (6/11-8/21)
July		
4	Friday	Independence Day – Holiday