Courses Taken by Recent Joint Program Naval Officers

Please Note: This is not an exhaustive list and there are other courses that JP Navy students can take. Students must take graduate level (G) classes to meet credit requirements, unless they get express permission. See [MIT Subject Listings]() for more information.

Civil Engineering

1.125 Architecting and Engineering Software Systems
Prereq: None, Units: 12
Software architecting and design of cloud-based software-intensive systems. Targeted at future engineering managers who must understand both the business and technical issues involved in architecting enterprise-scale systems. Student teams confront technically challenging problems. Introduces modern dev-ops concepts and cloud-computing, including cloud orchestration for machine learning. Also discusses cyber-security issues of key management and use of encrypted messaging for distributed ledgers, e.g., blockchain. Students face problem solving in an active learning lab setting, completing in-class exercises and weekly assignments leading to a group project. Some programming experience preferred. Enrollment limited.
J. Williams

1.813[J] Technology, Globalization, and Sustainable Development
Prereq: Permission of instructor, Units: 12
Investigates sustainable development, taking a broad view to include not only a healthy economic base, but also a sound environment, stable and rewarding employment, adequate purchasing power and earning capacity, distributional equity, national self-reliance, and maintenance of cultural integrity. Explores national, multinational, and international political and legal mechanisms to further sustainable development through transformation of the industrial state. Addresses the importance of technological innovation and the financial crisis of 2008 and the emergence of the Covid-19 pandemic, Russia's invasion of Ukraine, and inflation, as well as governmental interventions to reduce inequality.
N. Ashford

Mechanical Engineering

2.062[J] Wave Propagation
Prereq: 2.003, 18.075, Units: 12
Theoretical concepts and analysis of wave problems in science and engineering with examples chosen from elasticity, acoustics, geophysics, hydrodynamics, blood flow, nondestructive evaluation, and other applications. Progressive waves, group velocity and dispersion, energy density and transport. Reflection, refraction and transmission of plane waves by an interface. Mode conversion in elastic waves. Rayleigh waves. Waves due to a moving load. Scattering by a two-dimensional obstacle. Reciprocity theorems. Parabolic approximation. Waves on the sea surface. Capillary-gravity waves. Wave resistance. Radiation of surface waves. Internal waves in stratified fluids. Waves in rotating media. Waves in random media.
T. R. Akylas, R. R. Rosales

2.066 Acoustics and Sensing
Prereq: 2.003, 6.3000, 8.03, 16.003, or permission of instructor, Units: 12
Introduces the fundamental concepts of acoustics and sensing with waves. Provides a unified theoretical approach to the physics of image formation through scattering and wave propagation in sensing. The linear and nonlinear acoustic wave equation, sources of sound, including musical instruments. Reflection, refraction, transmission and absorption. Bearing and range estimation by sensor array processing, beamforming, matched filtering, and focusing. Diffraction, bandwidth, ambient noise and reverberation limitations. Scattering from objects, surfaces and volumes by Green's Theorem. Forward scatter, shadows, Babinet's principle, extinction and attenuation. Ray tracing and waveguides in remote sensing. Applications to acoustic, radar, seismic, thermal and optical sensing and exploration. Students taking the graduate version of the subject complete additional assignments.
N. C. Makris

2.096[J] Introduction to Modeling and Simulation
Prereq: 18.03 or 18.06, Units: 12
Introduction to computational techniques for modeling and simulation of a variety of large and complex engineering, science, and socio-economical systems. Prepares students for practical use and development of computational engineering in their own research and future work. Topics include mathematical formulations (e.g., automatic assembly of constitutive and conservation principles); linear system solvers (sparse and iterative); nonlinear solvers (Newton and homotopy); ordinary, time-periodic and partial differential equation solvers; and model order reduction. Students develop their own models and simulators for self-proposed applications, with an emphasis on creativity, teamwork, and communication. Prior basic linear algebra required and at least one numerical programming language (e.g., MATLAB, Julia, Python, etc.) helpful.
L. Daniel

2.120 Introduction to Robotics
Prereq: 2.004 or permission of instructor, 12 units
Cross-disciplinary studies in robot mechanics and intelligence. Emphasizes physical understanding of robot kinematics and dynamics, differential motion and energy method, design and control of robotic arms and mobile robots, and actuators, drives, and transmission. Second half of course focuses on algorithmic thinking and computation, computer vision and perception, planning and control for manipulation, localization and navigation, machine learning for robotics, and human-robot systems. Weekly laboratories include brushless DC motor control, design and fabrication of robotic arms and vehicles, robot vision and navigation, and programming and system integration using Robot Operating System (ROS). Group term project builds intelligent robots for specific applications of interest. Students taking graduate version complete additional assignments. Enrollment may be limited due to laboratory capacity.
H. Asada

2.122 Stochastic Systems
Prereq: 2.004 and 2.087, Units: 12
Response of systems to stochastic excitation with design applications. Linear time-invariant systems, convolution, Fourier and Laplace transforms. Probability and statistics. Discrete and continuous random variables, derived distributions. Stochastic processes, auto-correlation. Stationarity and ergodicity, power spectral density. Systems driven by random functions, Wiener-Khinchine theorem. Sampling and filtering. Short- and long-term statistics, statistics of extremes. Problems from mechanical vibrations and statistical linearization, statistical mechanics, and system prediction/identification. Students taking graduate version complete additional assignments and a short-term project.
T. P. Sapsis

2.131 Advanced Instrumentation and Measurement
Prereq: Permission of instructor, Units: 12
Provides training in advanced instrumentation and measurement techniques. Topics include system level design, fabrication and evaluation with emphasis on systems involving concepts and technology from mechanics, optics, electronics, chemistry and biology. Simulation, modeling and design software. Use of a wide range of instruments/techniques (e.g., scanning electron microscope, dynamic signal/system analyzer, impedance analyzer, laser interferometer) and fabrication/machining methods (e.g., laser micro-machining, 3D printing, computer controlled turning, and machining centers). Theory and practice of both linear and nonlinear system identification techniques. Lab sessions include instruction and group project work. No final exam.
I. W. Hunter

2.151 Advanced System Dynamics and Control
Prereq: 2.004 and (2.087 or 18.06), Units: 12

Analytical descriptions of state-determined dynamic physical systems; time and frequency domain representations; system characteristics - controllability, observability, stability; linear and nonlinear system responses. Modification of system characteristics using feedback. State observers, Kalman filters. Modeling/performance trade-offs in control system design. Basic optimization tools. Positive systems. Emphasizes applications to physical systems.
N. Hogan

2.154 Maneuvering and Control of Surface and Underwater Vehicles
Prereq: 2.22, Units: 12
Maneuvering motions of surface and underwater vehicles. Derivation of equations of motion, hydrodynamic coefficients. Memory effects. Linear and nonlinear forms of the equations of motion. Control surfaces modeling and design. Engine, propulsor, and transmission systems modeling and simulation during maneuvering. Stability of motion. Principles of multivariable automatic control. Optimal control, Kalman filtering, loop transfer recovery. Term project: applications chosen from autopilots for surface vehicles; towing in open seas; remotely operated vehicles.
N. Patrikalakis

2.160 Identification, Estimation, and Learning
Prereq: 2.151, 6.7100, 16.31, or permission of instructor, Units: 12
Provides a broad theoretical basis for estimation, identification, and learning of linear and nonlinear systems at the cross-disciplinary area of system dynamics and control, machine learning, and statistics. Recursive least squares estimate, partial least squares, Kalman filter and extended Kalman filter, Bayes filter and particle filter; parametric and non-parametric system identification, Wiener-Hopf equation, persistent excitation, unbiased estimates, asymptotic variance, experiment design; function approximation theory, neural nets, radial basis functions, Koopman operator for exact linearization of nonlinear systems, and dynamic mode decomposition. Context-oriented mini-projects: robotics, self-driving cars, biomedical engineering, wearable sensors.
H. Asada

2.168 Learning Machines
Prereq: None, Units: 12
Introduces fundamental concepts and encourages open-ended exploration of the increasingly topical intersection between artificial intelligence and the physical sciences. Energy and information, and their respective optimality conditions are used to define supervised and unsupervised learning algorithms; as well as ordinary and partial differential equations. Subsequently, physical systems with complex constitutive relationships are drawn from elasticity, biophysics, fluid mechanics, hydrodynamics, acoustics, and electromagnetics to illustrate how machine learning-inspired optimization can approximate solutions to forward and inverse problems in these domains.
G. Barbastathis

2.20 Marine Hydrodynamics
Prereq: 1.060, 2.006, 2.016, or 2.06, Units: 12
The fundamentals of fluid mechanics are developed in the context of naval architecture and ocean science and engineering. Transport theorem and conservation principles. Navier-Stokes' equation. Dimensional analysis. Ideal and potential flows. Vorticity and Kelvin's theorem. Hydrodynamic forces in potential flow, D'Alembert's paradox, added-mass, slender-body theory. Viscous-fluid flow, laminar and turbulent boundary layers. Model testing, scaling laws. Application of potential theory to surface waves, energy transport, wave/body forces. Linearized theory of lifting surfaces. Experimental project in the towing tank or propeller tunnel.
D. Yue

2.24[J] Seakeeping of Ships and Offshore Energy Systems
Prereq: 2.20 and 18.085, Units: 12

Surface wave theory, conservation laws and boundary conditions, properties of regular surface waves and random ocean waves. Linearized theory of floating body dynamics, kinematic and dynamic free surface conditions, body boundary conditions. Simple harmonic motions. Diffraction and radiation problems, added mass and damping matrices. General reciprocity identities on diffraction and radiation. Ship wave resistance theory, Kelvin wake physics, ship seakeeping in regular and random waves. Discusses point wave energy absorbers, beam sea and head-sea devises, oscillating water column device and Well's turbine. Discusses offshore floating energy systems and their interaction with ambient waves, current and wind, including oil and gas platforms, liquefied natural gas (LNG) vessels and floating wind turbines. Homework drawn from real-world applications.
P. D. Sclavounos

2.290 Numerical Fluid Mechanics
Prereq: 2.005, Units: 12
Introduction to numerical methods and MATLAB: errors, condition numbers and roots of equations. Navier-Stokes. Direct and iterative methods for linear systems. Finite differences for elliptic, parabolic and hyperbolic equations. Fourier decomposition, error analysis and stability. High-order and compact finite-differences. Finite volume methods. Time marching methods. Navier-Stokes solvers. Grid generation. Finite volumes on complex geometries. Finite element methods. Spectral methods. Boundary element and panel methods. Turbulent flows. Boundary layers. Lagrangian Coherent Structures. Includes a final research project. Students taking graduate version complete additional assignments.
Staff

2.611 Marine Power and Propulsion
Prereq: 2.005, Units: 12
Selection and evaluation of commercial and naval ship power and propulsion systems. Analysis of propulsors, prime mover thermodynamic cycles, propeller-engine matching. Propeller selection, waterjet analysis, review of alternative propulsors; thermodynamic analyses of Rankine, Brayton, Diesel, and Combined cycles, reduction gears and integrated electric drive. Battery operated vehicles, fuel cells. Term project requires analysis of alternatives in propulsion plant design for given physical, performance, and economic constraints. Graduate students complete different assignments and exams.
R. McCord

2.680 Unmanned Marine Vehicle Autonomy, Sensing, and Communication
Prereq: Permission of instructor, Units: 12
Focuses on software and algorithms for autonomous decision making (autonomy) by underwater vehicles operating in ocean environments. Discusses how autonomous marine vehicles (UMVs) adapt to the environment for improved sensing performance. Covers sensors for acoustic, biological and chemical sensing and their integration with the autonomy system for environmentally adaptive undersea mapping and observation. Introduces students to the underwater acoustic communication environment and various options for undersea navigation, highlighting their relevance to the operation of collaborative undersea networks for environmental sensing. Labs involve the use of the MOOP-IvP autonomy software for the development of integrated sensing, modeling and control solutions. Solutions modeled in simulation environments and include field tests with small autonomous surface and underwater vehicles operated on the Charles River. Limited enrollment.
Staff

2.681 Environmental Ocean Acoustics
Prereq: 2.066, 18.075, or permission of instructor, Units: 12
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

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. Highly recommended for all JP Navy students.
K. Foote, J. Colosi

2.682 Acoustical Oceanography
Prereq: 2.681, Units: 12
Provides 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. Addresses the acoustic inverse problem, reviewing inverse methods (linear and nonlinear) and the combination of acoustical methods with other measurements as an integrated system. Concentrates on specific case studies, taken from current research journals.
Staff

2.688 Principles of Oceanographic Instrument Systems -- Sensors and Measurements
Prereq: 2.671 and 18.075, Units: 12
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.
T. Maksym, WHOI Staff

2.710 Optics
Prereq: (Physics II (GIR), 2.004, and 18.03) or permission of instructor, Units: 12
Introduction to optical science with elementary engineering applications. Geometrical optics: ray-tracing, aberrations, lens design, apertures and stops, radiometry and photometry. Wave optics: basic electrodynamics, polarization, interference, wave-guiding, Fresnel and Fraunhofer diffraction, image formation, resolution, space-bandwidth product. Emphasis on analytical and numerical tools used in optical design. Graduate students are required to complete additional assignments with stronger analytical content, and an advanced design project.
G. Barbastathis, Tadesse

2.996 Advanced Topics in Mechanical Engineering
Prereq: Permission of instructor, Units arranged
Assigned reading and problems or research in distinct areas, either theoretical or experimental, or design. Arranged on individual basis with instructor in the following areas: mechanics and materials, thermal and fluid sciences, systems and design, biomedical engineering, and ocean engineering. Can be repeated for credit only for completely different subject matter.
M. Culpepper

2.S981 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor, Units arranged
Advanced lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
J. Kim

2.S997 Graduate Special Subject in Mechanical Engineering
Prereq: Permission of instructor, Units: arranged

Advanced lecture, seminar, or laboratory consisting of material not offered in regularly scheduled subjects. Can be repeated for credit only for completely different subject matter. 2.S980 and 2.S996 are graded P/D/F.
J. Kim

2.THG Graduate Thesis
Prereq: Permission of advisor, Units arranged
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.

Electrical Engineering and Computer Science

6.100A Introduction to Computer Science Programming in Python
Prereq: None, Units: 6
Introduction to computer science and programming. Students develop skills to program and use computational techniques to solve problems. Topics include: the notion of computation, Python, simple algorithms and data structures, object-oriented programming, testing and debugging, and algorithmic complexity. Lectures are viewed outside of class; in-class time is dedicated to problem-solving and discussion. Combination of 6.100A and 6.100B (or 16.C20) counts as REST subject.
A. Bell

6.100B Introduction to Computational Thinking and Data Science
Prereq: 6.100A or permission of instructor, Units: 6
Provides an introduction to using computation to build models that can be used to help understand real-world phenomena. Topics include optimization problems, simulation models, and statistical models. Requires experience programming in Python as a prerequisite. Combination of 6.100A and 6.100B counts as REST subject.
A. Bell

6.3000 Signal Processing
Prereq: 6.100A, Units: 12
Fundamentals of signal processing, focusing on the use of Fourier methods to analyze and process signals such as sounds and images. Topics include Fourier series, Fourier transforms, the Discrete Fourier Transform, sampling, convolution, deconvolution, filtering, noise reduction, and compression. Applications draw broadly from areas of contemporary interest with emphasis on both analysis and design.
D. Freeman

6.3010 Signals, Systems and Inference
Prereq: 6.3000 and (6.3700, 6.3800, or 18.05), Units: 12
Covers signals, systems and inference in communication, control and signal processing. Topics include input-output and state-space models of linear systems driven by deterministic and random signals; time- and transform-domain representations in discrete and continuous time; and group delay. State feedback and observers. Probabilistic models; stochastic processes, correlation functions, power spectra, spectral factorization. Least-mean square error estimation; Wiener filtering. Hypothesis testing; detection; matched filters.
Staff

6.3702 Introduction to Probability
Prereq: Calculus II (GIR), Units: 12
An introduction to probability theory, the modeling and analysis of probabilistic systems, and elements of statistical inference. Probabilistic models, conditional probability. Discrete and continuous random variables. Expectation and conditional expectation, and further topics about random variables. Limit Theorems. Bayesian estimation and hypothesis testing. Elements of classical statistical inference. Bernoulli and Poisson processes. Markov chains. Students

taking graduate version complete additional assignments.
Fall: *W. Oliver*   Spring: *P. Golland*

6.3900 Introduction to Machine Learning
Prereq: (6.1010 or 6.1210) and (18.03, 18.06, 18.700, or 18.C06), Units: 12
Introduction to the principles and algorithms of machine learning from an optimization perspective. Topics include linear and non-linear models for supervised, unsupervised, and reinforcement learning, with a focus on gradient-based methods and neural-network architectures. Previous experience with algorithms may be helpful.
S. Shen

6.4132[J] Principles of Autonomy and Decision Making
Prereq: 6.100B, 6.9080, or permission of instructor, Units: 12
Surveys decision making methods used to create highly autonomous systems and decision aids. Applies models, principles and algorithms taken from artificial intelligence and operations research. Focuses on planning as state-space search, including uninformed, informed and stochastic search, activity and motion planning, probabilistic and adversarial planning, Markov models and decision processes, and Bayesian filtering. Also emphasizes planning with real-world constraints using constraint programming. Includes methods for satisfiability and optimization of logical, temporal and finite domain constraints, graphical models, and linear and integer programs, as well as methods for search, inference, and conflict-learning. Students taking graduate version complete additional assignments.
A. Bobu

6.5620[J] Foundations of Cryptography
Prereq: 6.1220, 6.1400, or 18.4041, Units: 12
A rigorous introduction to modern cryptography. Emphasis on the fundamental cryptographic primitives such as public-key encryption, digital signatures, and pseudo-random number generation, as well as advanced cryptographic primitives such as zero-knowledge proofs, homomorphic encryption, and secure multiparty computation.
Y. Kalai

6.7000 Discrete-Time Signal Processing
Prereq: 6.3010, Units: 12
Representation, analysis, and design of discrete time signals and systems. Decimation, interpolation, and sampling rate conversion. Noise shaping. Flowgraph structures for DT systems. IIR and FIR filter design techniques. Parametric signal modeling, linear prediction, and lattice filters. Discrete Fourier transform, DFT computation, and FFT algorithms. Spectral analysis, time-frequency analysis, relation to filter banks. Multirate signal processing, perfect reconstruction filter banks, and connection to wavelets.
Staff

6.7020 Array Processing
Prereq: 6.7000 and (2.687 or (6.3010 and 18.06)), Units: 12
Adaptive and non-adaptive processing of signals received at arrays of sensors. Deterministic beamforming, space-time random processes, optimal and adaptive algorithms, and the sensitivity of algorithm performance to modeling errors and limited data. Methods of improving the robustness of algorithms to modeling errors and limited data are derived. Advanced topics include an introduction to matched field processing and physics-based methods of estimating signal statistics. Homework exercises providing the opportunity to implement and analyze the performance of algorithms in processing data supplied during the course.
Staff

6.7300[J] Introduction to Modeling and Simulation
Prereq: 18.03 or 18.06, Units: 12

Introduction to computational techniques for modeling and simulation of a variety of large and complex engineering, science, and socio-economical systems. Prepares students for practical use and development of computational engineering in their own research and future work. Topics include mathematical formulations (e.g., automatic assembly of constitutive and conservation principles); linear system solvers (sparse and iterative); nonlinear solvers (Newton and homotopy); ordinary, time-periodic and partial differential equation solvers; and model order reduction. Students develop their own models and simulators for self-proposed applications, with an emphasis on creativity, teamwork, and communication. Prior basic linear algebra required and at least one numerical programming language (e.g., MATLAB, Julia, Python, etc.) helpful.
L. Daniel

6.7470 Information Theory
Prereq: 6.3700, Units: 12
Mathematical definitions of information measures, convexity, continuity, and variational properties. Lossless source coding; variable-length and block compression; Slepian-Wolf theorem; ergodic sources and Shannon-McMillan theorem. Hypothesis testing, large deviations and I-projection. Fundamental limits of block coding for noisy channels: capacity, dispersion, finite blocklength bounds. Coding with feedback. Joint source-channel problem. Rate-distortion theory, vector quantizers. Advanced topics include Gelfand-Pinsker problem, multiple access channels, broadcast channels (depending on available time).
M. Medard, L. Zheng

6.7800 Inference and Information
Prereq: 6.3700, 6.3800, or 6.7700, Units: 12
Introduction to principles of Bayesian and non-Bayesian statistical inference and its information theoretic foundations. Hypothesis testing and parameter estimation, sufficient statistics, exponential families. Loss functions, information measures, model capacity, and information geometry. Variational inference and EM algorithm; MCMC and other Monte Carlo methods. Asymptotic analysis and large deviations theory; universal inference and learning. Selected topics such as representation learning, score-matching, diffusion, and nonparametric statistics.
Staff

6.8300 Advances in Computer Vision
Prereq: (6.1200 or 6.3700) and (18.06 or 18.C06), Units: 12
Advanced topics in computer vision with a focus on the use of machine learning techniques and applications in graphics and human-computer interface. Covers image representations, texture models, structure-from-motion algorithms, Bayesian techniques, object and scene recognition, tracking, shape modeling, and image databases. Applications may include face recognition, multimodal interaction, interactive systems, cinematic special effects, and photorealistic rendering. Covers topics complementary to 6.8390.
Staff

6.9280[J] Leading Creative Teams
Prereq: Permission of instructor, Units: 9
Prepares students to lead teams charged with developing creative solutions in engineering and technical environments. Grounded in research but practical in focus, equips students with leadership competencies such as building self-awareness, motivating and developing others, creative problem solving, influencing without authority, managing conflict, and communicating effectively. Teamwork skills include how to convene, launch, and develop various types of teams, including project teams. Learning methods emphasize personalized and experiential skill development. Enrollment limited.
D. Nino

6.9500 Introduction to MATLAB
Prereq: None, Units: 3 [P/D/F]

Accelerated introduction to MATLAB and its popular toolboxes. Lectures are interactive, with students conducting sample MATLAB problems in real time. Includes problem-based MATLAB assignments. Students must provide their own laptop and software. Enrollment limited.
Consult Department

6.9510 Introduction to Signals and Systems, and Feedback Control
Prereq: Calculus II (GIR) or permission of instructor, Units: 6 [P/D/F]
Introduces fundamental concepts for 6.003, including Fourier and Laplace transforms, convolution, sampling, filters, feedback control, stability, and Bode plots. Students engage in problem solving, using Mathematica and MATLAB software extensively to help visualize processing in the time frequency domains.
Consult Department

6.9570 Introduction to C and C++
Prereq: None, Units: 6 [P/D/F]
Fast-paced introduction to the C and C++ programming languages. Intended for those with experience in other languages who have never used C or C++. Students complete daily assignments, a small-scale individual project, and a mandatory online diagnostic test. Enrollment limited.
Consult Department

6.S191 Special Lab Subject in Electrical Engineering and Computer Science
Prereq: Permission of instructor, Units arranged [P/D/F]
Laboratory subject that covers content not offered in the regular curriculum. Consult department to learn of offerings for a particular term.
Staff

Biology

7.411 Seminars in Biological Oceanography
Prereq: Permission of instructor, Units arranged [P/D/F]
Selected topics in biological oceanography.
WHOI Staff

Earth, Atmosphere and Planetary Science

12.310 An Introduction to Weather Forecasting
Prereq: Calculus I (GIR) and Physics I (GIR), Units: 6 [P/D/F]
Basic principles of synoptic meteorology and weather forecasting. Analysis of hourly weather data and numerical weather prediction models. Regular preparation of weather forecasts.
T. Tamarin Brodsky

12.446 Teaching Experience in EAPS
Prereq: None, Units arranged [P/D/F]
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.
Ann Greaney-Williams

12.702 Elements of Modern Oceanography
Prereq: None, Units: 12

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.
WHOI Staff

12.714 Computational Data Analysis
Prereq: 18.03, Units: 12
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

12.742 Marine Chemistry
Prereq: Permission of instructor, Units: 12
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. Wankel, T. Horner

12.800 Fluid Dynamics of the Atmosphere and Ocean
Prereq: 8.03 and 18.04, Units: 12
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

12.801 Large-scale Ocean Dynamics
Prereq: 12.800, Units: 12
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.
Y. Kwon, J. Yang

12.802 Waves, Instability and Turbulence at Small Scales
Prereq: 12.800 or permission of instructor, Units: 12
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

12.805 Data Analysis in Physical Oceanography
Prereq: Permission of instructor, Units: 12
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, C. Piecuch

12.808 Introduction to Observational Physical Oceanography
Prereq: Permission of instructor, Units: 12
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.
I. Le Bras, S. Ryan

12.810 Dynamics of the Atmosphere
Prereq: 12.800, Units: 12
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, Units: 12
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.
Staff

12.842 Climate Science
Prereq: Chemistry (GIR), 18.03, or permission of instructor, Units: 12
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, D. McGee

12.850 Computational Ocean Modeling
Prereq: None, Units: 12
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. Bodner, A. Mahadevan

12.860 Climate Variability and Diagnostics
Prereq: Permission of instructor, Units: 12
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.
A. Gonzalez

12.870 Air-Sea Interaction: Boundary Layers
Prereq: Graduate-level fluid mechanics and a subject on waves or permission of instructor, Units: 12
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.
T. Farrar, M. Hell

12.885[J] Science, Politics, and Environmental Policy
Prereq: Permission of instructor, Units: 12
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 graduate version complete different assignments. Limited to 22.
S. Solomon, J. Knox-Hayes

12.S593 Special Seminar in Earth, Atmospheric and Planetary Sciences
Prereq: Permission of instructor, Units arranged [P/D/F]
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

12.981 Current Research in MIT-WHOI Joint Program at MIT
Prereq: Permission of instructor, Units arranged [P/D/F]
Original investigations, laboratory work, or fieldwork in oceanography. For JP students with advisors at MIT.

12.983 Current Research in MIT-WHOI Joint Program
Prereq: Permission of instructor, Units arranged [P/D/F]
Original investigations, laboratory work, or fieldwork in oceanography. For JP students with advisors at WHOI.

12.THG Graduate Thesis
Prereq: Permission of instructor, Units arranged
Program of research leading to the writing of an SM, PhD, or ScD thesis which may involve field work; to be arranged by the student and an appropriate MIT faculty member. For MIT-WHOI Joint Program students, a WHOI faculty member may also be appropriate.

Management

15.071: The Analytics Edge
Prereq: 15.060, Units: 12
Develops models and tools of data analytics that are used to transform businesses and industries, using examples and case studies in e-commerce, healthcare, social media, high technology, criminal justice, the internet, and beyond. Covers analytics methods such as linear regression, logistic regression, classification trees, random forests, neural networks, text analytics, social network analysis, time series modeling, clustering, and optimization. Uses mostly R programming language and some work in Jupyter notebooks. Includes team project. Meets with 15.0711 when offered concurrently. Expectations and evaluation criteria differ for students taking graduate version; consult syllabus or instructor for specific details.
Fall: *P. Sun* Spring: *R. Freund, S. Gupta*

15.236 Global Business of Artificial Intelligence and Robotics (GBAIR)
Prereq: Permission of instructor, Units: 6
Discussion based-course examines applications of artificial intelligence and robotics in the business world. Emphasizes understanding the likely direction of technology and how it is likely to be used. Students examine particular applications to deepen their understanding of topical issues. Also focuses on how global economies will change in light of this wave of technology. Preference to Sloan graduate students.
J. Ruane, S. Johnson

15.286 Communicating with Data
Prereq: 15.280, 15.284, or permission of instructor, Units: 6
Focuses on structuring the oral and visual communication of data. Introduces these concepts and a methodology of self-reflection to help students accelerate their life-long learning process. Improves students' ability to develop strategic communications that use data to persuade others to take action. Primary focus is on reducing barriers to action by making data as easy as possible for others to absorb through clear structure, clear design, and clear delivery. Significant time will be devoted to practice. Students give and receive substantial feedback on their work.
M. Kazakoff, A. Mehrotra

15.672 Negotiation Analysis
Prereq: Permission of instructor, Units: 3 [P/D/F]
Presents analytical frameworks and strategies to handle a variety of negotiation situations. Includes simulations, games, videos, lectures, discussion, and multiple opportunities to practice and hone negotiation, communication, and influence skills with extensive personalized feedback. Intended for students with a broad spectrum of backgrounds and experience levels. Six-unit version includes additional class time and outside work. Expectations and evaluation criteria differ for students taking graduate version. Limited to 80 via lottery; consult class website for information and deadlines.
J. Curhan

15.775 Analytics Proseminar
Prereq: None, Units: 3 [P/D/F]
Provides opportunities to meet senior executives serving in top analytics and data science functions within a variety of organizations across industries. Discusses key business analytics issues from the perspective of top management. Students prepare detailed briefings identifying and exploring important analytics issues facing these organizations.
Staff

15.818 Pricing
Prereq: 15.809, 15.814, or permission of instructor, Units: 6
Framework for understanding pricing strategies and analytics, with emphasis on entrepreneurial pricing. Topics include economic value analysis, elasticities, customization, complementary products, pricing in platform markets, and anticipating competitive responses.
Staff

Aeronautics and Astronautics

16.002 Unified Engineering: Signals and Systems
Prereq: Calculus II (GIR); Coreq: Physics II (GIR), 16.001, and (18.03 or 18.032), Units: 12
Presents fundamental principles and methods of signals and systems for aerospace engineering, and engineering analysis and design concepts applied to aerospace systems. Topics include linear and time invariant systems; convolution; Fourier and Laplace transform analysis in continuous and discrete time; modulation, filtering, and sampling; and an introduction to feedback control. Experiential lab and system projects provide additional aerospace context. Labs, projects, and assignments involve the use of software such as MATLAB and/or Python.
S.R. Hall

16.391 Statistics for Engineers and Scientists
Prereq: Calculus II (GIR), 18.06, 6.431, or permission of instructor, Units: 12
Rigorous introduction to fundamentals of statistics motivated by engineering applications. Topics include exponential families, order statistics, sufficient statistics, estimation theory, hypothesis testing, measures of performance, notions of optimality, analysis of variance (ANOVA), simple linear regression, and selected topics.
M. Win

Political Science

17.448[J] Cybersecurity
Prereq: Permission of instructor, Units: 12
Focuses on the complexity of cybersecurity in a changing world. Examines national and international aspects of overall cyber ecology. Explores sources and consequences of cyber threats and different types of damages. Considers impacts for and of various aspects of cybersecurity in diverse geostrategic, political, business and economic contexts. Addresses national and international policy responses as well as formal and informal strategies and mechanisms for responding to cyber insecurity and enhancing conditions of cybersecurity. Students taking graduate version expected to pursue subject in greater depth through reading and individual research.
N. Choucri, S. Madnick, A. Pentland

17.910 Reading Seminar in Social Science
Prereq: None, Units arranged
Reading and discussion of special topics in the fields of social science. Open to advanced undergraduates by arrangement with individual staff members. 17.909 is taught P/D/F.
Staff

Mathematics

18.03 Differential Equations
Prereq: None. Coreq: Calculus II (GIR), Units: 12
Study of differential equations, including modeling physical systems. Solution of first-order ODEs by analytical, graphical, and numerical methods. Linear ODEs with constant coefficients. Complex numbers and exponentials. Inhomogeneous equations: polynomial, sinusoidal, and exponential inputs. Oscillations, damping, resonance. Fourier series. Matrices,

eigenvalues, eigenvectors, diagonalization. First order linear systems: normal modes, matrix exponentials, variation of parameters. Heat equation, wave equation. Nonlinear autonomous systems: critical point analysis, phase plane diagrams.
S. Dyatlov

18.0651 Matrix Methods in Data Analysis, Signal Processing, and Machine Learning
Prereq: 18.06, Units: 12
Reviews linear algebra with applications to life sciences, finance, engineering, and big data. Covers singular value decomposition, weighted least squares, signal and image processing, principal component analysis, covariance and correlation matrices, directed and undirected graphs, matrix factorizations, neural nets, machine learning, and computations with large matrices. Students in Course 18 must register for the undergraduate version, 18.065.
Staff

18.0851 and 18.085 Computational Science and Engineering I
Prereq: Calculus II (GIR) and (18.03 or 18.032), Units: 12
Review of linear algebra, applications to networks, structures, and estimation, finite difference and finite element solution of differential equations, Laplace's equation and potential flow, boundary-value problems, Fourier series, discrete Fourier transform, convolution. Frequent use of MATLAB in a wide range of scientific and engineering applications. Students in Course 18 must register for the undergraduate version, 18.085.
Fall: *D. Kouskoulas* Summer: *Staff*

18.089 Review of Mathematics
Prereq: Permission of instructor, Units: 12
One-week review of one-variable calculus (18.01), followed by concentrated study covering multivariable calculus (18.02), two hours per day for five weeks. Primarily for graduate students in Course 2N. Degree credit allowed only in special circumstances.
Staff

18.305 Advanced Analytic Methods in Science and Engineering
Prereq: 18.04, 18.075, or 18.112, Units: 12
Covers expansion around singular points: the WKB method on ordinary and partial differential equations; the method of stationary phase and the saddle point method; the two-scale method and the method of renormalized perturbation; singular perturbation and boundary-layer techniques; WKB method on partial differential equations.
Staff

18.600 Probability and Random Variables
Prereq: Calculus II (GIR), Units: 12
Probability spaces, random variables, distribution functions. Binomial, geometric, hypergeometric, Poisson distributions. Uniform, exponential, normal, gamma and beta distributions. Conditional probability, Bayes theorem, joint distributions. Chebyshev inequality, law of large numbers, and central limit theorem. Credit cannot also be received for 6.041A or 6.041B.
S. Sheffield

Humanities: Writing

21W.794 Graduate Technical Writing Workshop
Prereq: Permission of instructor, Units: 3
Designed to improve the student's ability to communicate technical information. Covers central communication concepts and techniques, including audience, discourse, and genre analysis; strategies for effectively managing, integrating, and documenting information from sources; and methods of structuring information for coherence and credibility. Assignments include an abstract, a literature review, and an oral presentation; students provide feedback to

each other. Limited to graduate engineering students based on results of the Graduate Writing Exam.
A. Karatsolis

Institute for Data, Systems and Society

IDS.012[J] Statistics, Computation and Applications
Prereq: (6.100B, (18.03, 18.06, or 18.C06), and (6.3700, 6.3800, 14.30, 16.09, or 18.05)) or permission of instructor, Units: 12
Hands-on analysis of data demonstrates the interplay between statistics and computation. Includes four modules, each centered on a specific data set, and introduced by a domain expert. Provides instruction in specific, relevant analysis methods and corresponding algorithmic aspects. Potential modules may include medical data, gene regulation, social networks, finance data (time series), traffic, transportation, weather forecasting, policy, or industrial web applications. Projects address a large-scale data analysis question. Students taking graduate version complete additional assignments. Enrollment limited; priority to Statistics and Data Science minors, and to juniors and seniors.
C. Uhler, N. Azizan, M. Roozbehani

IDS.437[J] Technology, Globalization, and Sustainability Development
Prereq: Permission of instructor, Units: 12
Investigates sustainable development, taking a broad view to include not only a healthy economic base, but also a sound environment, stable and rewarding employment, adequate purchasing power and earning capacity, distributional equity, national self-reliance, and maintenance of cultural integrity. Explores national, multinational, and international political and legal mechanisms to further sustainable development through transformation of the industrial state. Addresses the importance of technological innovation and the financial crisis of 2008 and the emergence of the Covid-19 pandemic, Russia's invasion of Ukraine, and inflation, as well as governmental interventions to reduce inequality.
N. Ashford

Science, Technology, and Society

STS.471[J] Engineering Apollo: The Moon Project as a Complex System
Prereq: None, Units: 12
Detailed technical and historical exploration of the Apollo project to fly humans to the moon and return them safely to Earth as an example of a complex engineering system. Emphasizes how the systems worked, the technical and social processes that produced them, mission operations, and historical significance. Guest lectures by MIT-affiliated engineers who contributed to and participated in the Apollo missions. Students work in teams on a final project analyzing an aspect of the historical project to articulate and synthesize ideas in engineering systems.
J. A. Hoffman and D. Mindell