Courses Taken by Recent Joint Program Naval Officers

Civil Engineering

1.813 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 employment, adequate purchasing power, 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. 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, 2.04B, 6.003, 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 Numerical Simulation
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 and programming (e.g., MATLAB or Python) helpful.
L. Daniel

2.122 Stochastic Systems

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

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, stereo lithography, 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. Hunter

2.151 Advanced System Dynamics and Control

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. J. Slotine

2.154 Maneuvering and Control of Surface and Underwater Vehicles

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

Provides a broad theoretical basis for system identification, estimation, and learning. Least squares estimation and its convergence properties, Kalman filter and extended Kalman filter, noise dynamics and system representation, function approximation theory, neural nets, radial basis functions, wavelets, Volterra expansions, informative data sets, persistent excitation, asymptotic variance, central limit theorems, model structure selection, system order estimate, maximum likelihood, unbiased estimates, Cramer-Rao lower bound, Kullback-Leibler information distance, Akaike's information criterion, experiment design, and model validation. H. Asada, J.-J. E. Slotine

2.168 Learning Machines

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

2.290 Numerical Fluid Mechanics
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. P. F. J. Lermusiaux

2.611 Marine Power and Propulsion
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
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. H. Schmidt, J.J. Leonard, M. Benjamin

2.681 Environmental Ocean Acoustics
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

2.682 Acoustical Oceanography
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. J. F. Lynch, Woods Hole Staff

2.688 Principles of Oceanographic Instrument Systems -- Sensors and Measurements
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. A. Michel, S. Laney

2.689[J] Projects in Oceanographic Engineering
Projects in oceanographic engineering, carried out under supervision of Woods Hole Oceanographic Institution staff. Given at Woods Hole Oceanographic Institution. Woods Hole Staff

2.710 Optics
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. Staff

2.S981 Graduate Special Subject in Mechanical Engineering
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.
Staff

2.996 Advanced Topics in Mechanical Engineering
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.

2.S997 Graduate Special Subject in Mechanical Engineering
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. X. Zhao

Electrical Engineering and Computer Science

6.003 Signals and Systems
Presents the fundamentals of signal and system analysis. Topics include discrete-time and continuous-time signals, Fourier series and transforms, Laplace and Z transforms, and analysis of linear, time-invariant systems. Applications drawn broadly from engineering and physics, including audio and image processing, communications, and automatic control.
D. M. Freeman, Q. Hu, J. S. Lim

6.011 Signals, Systems and Inference
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. A. V. Oppenheim, G. C. Verghese

6.057 Introduction to MATLAB
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. A. Hunter

6.058 Introduction to Signals and Systems, and Feedback Control
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.

6.179 Introduction to C and C++
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. A. Hunter

6.S191 Special Lab Subject in Electrical Engineering and Computer Science
Covers subject matter not offered in the regular curriculum. Consult department to learn of offerings for a particular term. Staff

6.255 Optimization Methods
Introduces the principal algorithms for linear, network, discrete, robust, nonlinear, and dynamic optimization. Emphasizes methodology and the underlying mathematical structures. Topics include the simplex method, network flow methods, branch and bound and cutting plane methods for discrete optimization, optimality conditions for nonlinear optimization, interior point methods for convex optimization, Newton's method, heuristic methods, and dynamic programming and optimal control methods. Expectations and evaluation criteria differ for students taking graduate version; consult syllabus or instructor for specific details. S. Shtern

6.336[J] Introduction to Numerical Simulation
Introduction to computational techniques for the simulation of a large variety of engineering and engineered systems. Applications drawn from aerospace, mechanical, electrical, and chemical engineering, biology, and materials science. Topics: mathematical formulations; network problems; sparse direct and iterative matrix solution techniques; Newton methods for nonlinear problems; discretization methods for ordinary, time-periodic and partial differential equations; fast methods for partial differential equations and integral equations, techniques for model order reduction of dynamical systems and approaches for molecular dynamics. L. Daniel, J. K. White

6.341 Discrete-Time Signal Processing
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. J. Ward

6.431 Introduction to Probability I
An introduction to probability theory, and the modeling and analysis of probabilistic systems. Probabilistic models, conditional probability. Discrete and continuous random variables. Expectation and conditional expectation. Limit Theorems. An introduction to probability theory, and the modeling and analysis of probabilistic systems. Probabilistic models, conditional probability. Discrete and continuous random variables. Expectation and conditional expectation. Limit Theorems. Students taking graduate version complete additional assignments. P. Jaillet, J. N. Tsitsiklis

6.434 Statistics for Engineers
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

6.437 Inference and Information
Introduction to principles of Bayesian and non-Bayesian statistical inference. Hypothesis testing and parameter estimation, sufficient statistics; exponential families. EM agorithm. Log-loss inference criterion, entropy and model capacity. Kullback-Leibler distance and information geometry. Asymptotic analysis and large deviations theory. Model order estimation; nonparametric statistics. Computational issues and approximation techniques; Monte Carlo methods. Selected special topics such as universal prediction and compression. P. Golland, G. W. Wornell

6.431B Introduction to Probability II
Further topics in probability. Bayesian estimation and hypothesis testing. Elements of statistical inference. Bernoulli and Poisson processes. Markov chains. Students taking graduate version complete additional assignments. P. Jaillet, J. N. Tsitsiklis

6.441 Information Theory
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

6.456 Array Processing
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. J. Preisig, (J. Preisig, E. Fischell 2017)

6.869 Advances in Computer Vision
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 6.866. Students taking graduate version complete additional assignments. W. T. Freeman, A. Torralba

6.875 Cyrptography and Cryptanalysis
A rigorous introduction to modern cryptography. Emphasis on the fundamental cryptographic primitives of public-key encryption, digital signatures, pseudo-random number generation, and basic protocols and their computational complexity requirements. V. Vaikuntanathan

6.877 Principles of Autonomy and Decision Making
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. B. C. Williams

Earth, Atmosphere and Planetary Science

12.310 An Introduction to Weather Forecasting
Basic principles of synoptic meteorology and weather forecasting. Analysis of hourly weather data and numerical weather prediction models. Regular preparation of weather forecasts. L. Illari

12.446 Teaching Experience in EAPS
Recognizes the educational value derived from satisfactory performance of assigned duties as a Teaching Assistant. Laboratory, field, recitation, or classroom teaching under supervision of a faculty

member. Credit for this subject may not be used for any degree granted by Course 12. Total enrollment limited by availability of suitable teaching assignments.

12.702 Elements of Modern Oceanography
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. A. Kirincich, S. Laney

12.711 Marine Geology and Geophysics
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

12.714 Computational Data Analysis
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

12.800 Fluid Dynamics of the Atmosphere and Ocean
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 courses in atmospheric science, physical oceanography, ocean engineering, climate science, etc. Emphasizes fluid fundamentals, with an atmosphere/ocean twist. J. Marshall

12.801 Large-scale Ocean Dynamics
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
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. R. Ferrari

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

12.808 Introduction to Observational Physical Oceanography
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. C. Cenedese, A. Mahadevan

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

12.842 Climate Science
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. K. Emanuel, E. Boyle

12.850 Computational Ocean Modeling
Numerical modeling in oceanography and environmental fluid mechanics. Focuses on the building of computational models that describe processes such as transport (advection, diffusion), reaction (ecosystems), and boundary forcing, of relevance in the ocean. Models are developed in a hierarchical manner, starting from the simple (zero-dimensional in space), and incrementally advancing toward more complex, time-evolving systems in one-, two- (shallow water) and three-dimensions (Primitive

equations). Students build their own models using the finite volume approach with an appreciation and understanding of the working of general circulation models. A. Mahadevan, W. Zhang

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

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

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

Management

15.672 Negotiation Analysis
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

Aeronautics and Astronautics

16.002 Unified Engineering: Signals and Systems
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; transform analysis; and modulation, filtering, and sampling. Experiential lab and aerospace system projects provide additional aerospace context. H. Balakrishnan, D. L. Darmofal

Political Science

17.448 Cybersecurity
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

17.910 Reading Seminar in Social Science
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
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. Fall: J. Dunkel, Spring: D. Jerison

18.0851 and 18.085 Computational Science and Engineering I
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: G. Strang. Spring: P. Saenz

18.0651 Matrix Methods in Data Analysis, Signal Processing, and Machine Learning
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. G. Strang

18.089 Review of Mathematics
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. B. Peskin

18.305 Advanced Analytic Methods in Science and Engineering
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. H. Cheng

18.440 Probability and Random Variables
This course introduces students to probability and random variables. Topics include distribution functions, binomial, geometric, hypergeometric, and Poisson distributions. The other topics covered are uniform, exponential, normal, gamma and beta distributions; conditional probability; Bayes theorem; joint distributions; Chebyshev inequality; law of large numbers; and central limit theorem.

Humanities: Writing

21W.794 Graduate Technical Writing Workshop
This course focuses on improving your ability to communicate technical information. Through a combination of lecture, assignments, and in-class writing exercises, we will cover the basics of working with sources, including summarizing & paraphrasing, synthesizing source materials, citing, quoting, and avoiding plagiarism. We will also cover how to write an abstract and a literature review.

Institute for Data, Systems and Society

IDS.437 Technology, Globalization, and Sustainability Development
Investigates sustainable development, taking a broad view to include not only a healthy economic base, but also a sound environment, stable employment, adequate purchasing power, 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. N. Ashford

Science, Technology, and Society

STS.471 Engineering Apollo: The Moon Project as a Complex System
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. L. Young