18.014 Calculus with Theory
Prereq: None
U (Fall) 5-0-7 CALC I
Credit cannot also be received for 18.014, 18.01A, CC.181A, ES.1801, ES.181A

Covers the same material as 18.01, but at a deeper and more rigorous level. Emphasizes careful reasoning and understanding of proofs. Assumes knowledge of elementary calculus. Topics: axioms for the real numbers; the Riemann integral; limits, theorems on continuous functions; derivatives of functions of one variable; the fundamental theorems of calculus; Taylor’s theorem; infinite series, power series, rigorous treatment of the elementary functions.

J. Geiger

18.02 Calculus
Prereq: Calculus I (GIR) U (Fall, Spring) 5-0-7 CALC II
Credit cannot also be received for 18.02, 18.02A, 18.023, 18.024, CC.1802, CC.182A, ES.1802, ES.182A

Calculus of several variables. Topics as in 18.02 but with more focus on mathematical concepts. Vector algebra, dot product, matrices, determinant. Functions of several variables, continuity, differentiability, derivative. Parameterized curves, arc length, curvature, torsion. Vector fields, gradient, curl, divergence. Multiple integrals, change of variables, line integrals, surface integrals. Stokes’ theorem in one, two, and three dimensions.

O. Tamuz

18.03 Differential Equations
Prereq: Calculus I (GIR), permission of Instructor U (Spring) 5-0-7 REST
Credit cannot also be received for 18.03A, 18.03B, 18.03C, CC.1803, CC.1803A, CC.1803B, ES.1803

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,

Fall: L. Demanet
Spring: G. Staffilani, D. Jerison

18.034 Differential Equations
Prereq: None. Coreq: Calculus II (GIR)
U (Spring)
5-0-7 REST
Credit cannot also be received for 18.03, 18.036, CC.1803, ES.1803
Covers much of the same material as 18.03 with more emphasis on theory. The point of view is rigorous and results are proven. Local existence and uniqueness of solutions.

Information: G. Staffilani

18.04 Complex Variables with Applications
Prereq: Calculus II (GIR); 18.03 or 18.034
U (Spring)
4-0-8
Credit cannot also be received for 18.075
Complex algebra and functions; analyticity; contour integration, Cauchy's theorem; singularities, Taylor and Laurent series; residues, evaluation of integrals; multivalued functions, potential theory in two dimensions; Fourier analysis, Laplace transforms, and partial differential equations.

H. Cheng

18.05 Introduction to Probability and Statistics
Prereq: Calculus I (GIR)
U (Spring)
4-0-8 REST

J. Orloff

18.06 Linear Algebra
Prereq: Calculus II (GIR)
U (Fall, Spring)
4-0-8 REST
Credit cannot also be received for 18.700
Basic subject on matrix theory and linear algebra, emphasizing topics useful in other disciplines, including systems of equations, vector spaces, determinants, eigenvalues, singular value decomposition, and positive definite matrices. Applications to least-squares approximations, stability of differential equations, networks, Fourier transforms, and Markov processes. Uses MATLAB. Compared with 18.700, more emphasis on matrix algorithms and many applications.

Fall: A. Postnikov
Spring: G. Strang

18.062J Mathematics for Computer Science
(Same subject as 6.042J)
Prereq: Calculus I (GIR)
U (Fall, Spring)
5-0-7 REST
See description under subject 6.042J.
F. T. Leighton, A. R. Meyer, A. Moitra

18.075 Methods for Scientists and Engineers
Prereq: Calculus II (GIR); 18.03 or 18.034
G (Spring)
3-0-9 H-LEVEL Grad Credit (H except for Course 18 students)
Credit cannot also be received for 18.04
Covers functions of a complex variable; calculus of residues. Includes ordinary differential equations; Bessel and Legendre functions; Sturm-Liouville theory; partial differential equations; heat equation; and wave equations.

H. Cheng

18.085 Computational Science and Engineering I
Prereq: Calculus II (GIR); 18.03 or 18.034
G (Fall, Spring, Summer)
3-0-9 H-LEVEL Grad Credit (H except for Course 18 students)
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.

Fall: G. Strang
Spring: Information: G. Strang

18.086 Computational Science and Engineering II
Prereq: Calculus II (GIR); 18.03 or 18.034
G (Spring)
3-0-9 H-LEVEL Grad Credit (H except for Course 18 students)

Information: G. Strang

18.089 Review of Mathematics
Prereq: Permission of instructor
G (Summer)
5-0-7
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.

Information: G. Staffilani

18.094J Teaching College-Level Science and Engineering
(Same subject as 1.95J, 5.95J, 6.982J, 7.59J, 8.395J)
Prereq: None
G (Fall)
2-0-2 [P/D/F]
See description under subject 5.95J.
J. Rankin

18.095 Mathematics Lecture Series
Prereq: Calculus I (GIR)
U (IAP)
2-0-4 [P/D/F]
Ten lectures by mathematics faculty members on interesting topics from both classical and modern mathematics. All lectures accessible to students with calculus background and an interest in mathematics. At each lecture, reading and exercises are assigned. Students prepare these for discussion in a weekly problem session.

Information: G. Staffilani

18.098 Independent Study
Prereq: Permission of instructor
U (IAP)
Units arranged [P/D/F]
Can be repeated for credit
Studies or special individual reading arranged in consultation with individual faculty members and subject to departmental approval.

Information: G. Staffilani
18.099 Independent Study
Prereq: Permission of instructor
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit
Studies (during IAP) or special individual reading (during regular terms). Arranged in consultation with individual faculty members and subject to departmental approval.
Information: G. Staffilani

ANALYSIS

18.100A Real Analysis
Prereq: Calculus II (GIR); or 18.014 and Coreq: Calculus II (GIR)
G (Fall, Spring)
3-0-9 H-LEVEL Grad Credit H (except for Course 18 students)
Credit cannot also be received for 18.100B, 18.100C

18.100B Real Analysis
Prereq: Calculus II (GIR); or 18.014 and Coreq: Calculus II (GIR)
G (Fall, Spring)
3-0-9 H-LEVEL Grad Credit H (except for Course 18 students)
Credit cannot also be received for 18.100A, 18.100C

18.100C Real Analysis
Prereq: Calculus II (GIR); or 18.014 and Coreq: Calculus II (GIR)
U (Fall, Spring)
4-0-11
Credit cannot also be received for 18.100A, 18.100B

Three options offered, each covering fundamentals of mathematical analysis: convergence of sequences and series, continuity, differentiability, Riemann integral, sequences and series of functions, uniformity, interchange of limit operations. Each option shows the utility of abstract concepts and teaches understanding and construction of proofs. Option A: Proofs and definitions are less abstract. Gives applications where possible. Concerned primarily with the real line. Option B: More demanding; for students with more mathematical maturity. Places more emphasis on point-set topology and n-space. Option C: 15-unit (4-0-11) variant of Option B, with further instruction and practice in written communication. Enrollment limited in Option C.

Fall: 18.100A: P. Mattuck
18.100B: P. Isett
18.100C: E. Baer
Spring: 18.100A: S. Dyatlov
18.100B: J.-L. Kim
18.100C: R. Bezrukavnikov

18.101 Analysis and Manifolds
Prereq: 18.100; 18.06, 18.700, or 18.701
G (Fall)
3-0-9 H-LEVEL Grad Credit H (except for Course 18 students)
Introduction to the theory of manifolds: vector fields and densities on manifolds, integral calculus in the manifold setting and the manifold version of the divergence theorem. 18.901 helpful but not required.
V. W. Guillemin

18.102 Introduction to Functional Analysis
Prereq: 18.100; 18.06, 18.700, or 18.701
G (Spring)
3-0-9 H-LEVEL Grad Credit H (except for Course 18 students)
R. B. Meise

18.103 Fourier Analysis: Theory and Applications
Prereq: 18.100; 18.06, 18.700, or 18.701
G (Fall)
3-0-9 H-LEVEL Grad Credit H (except for Course 18 students)
Roughly half the subject devoted to the theory of the Lebesgue integral with applications to probability, and half to Fourier series and Fourier integrals.
L. Guth

18.104 Seminar in Analysis
Prereq: 18.100
U (Fall)
3-0-9
Students present and discuss material from books or journals. Topics vary from year to year. Instruction and practice in written and oral communication provided. Enrollment limited.
V. W. Guillemin

18.112 Riemann Surfaces
Prereq: 18.100; 18.06, 18.700, or 18.701
G (Spring)
3-0-9 H-LEVEL Grad Credit
Riemann surfaces, uniformization, Riemann-Roch Theorem. Theory of elliptic functions and modular forms. Some applications, such as to number theory.
T. Mrowka

18.116 Riemann Surfaces
Prereq: 18.112, 18.965
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
Riemann surfaces, uniformization, Riemann-Roch Theorem. Theory of elliptic functions and modular forms. Some applications, such as to number theory.
T. Mrowka

18.117 Topics in Several Complex Variables
Prereq: 18.112, 18.965
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Harmonic theory on complex manifolds, Hodge decomposition theorem, Hard Lefschetz theorem. Vanishing theorems. Theory of Stein manifolds. As time permits students also study holomorphic vector bundles on Kahler manifolds.
V. W. Guillemin

18.125 Real and Functional Analysis
Prereq: 18.100
G (Spring)
3-0-9 H-LEVEL Grad Credit
Provides a rigorous introduction to Lebesgue’s theory of measure and integration. Covers material that is essential in analysis, probability theory, and differential geometry.
D. W. Stroock

18.135 Geometric Analysis
Prereq: 18.745 or 18.755
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
A quick description of Riemannian symmetric spaces. Spherical functions and Harish-Chandra’s c-function. Fourier transforms and Radon transforms on Riemannian symmetric spaces X. Applications to invariant differential equations, in particular the multitemporal wave equation on X. Eigenspace representations.
S. Helgason
18.137 Topics in Geometric Partial Differential Equations
Prereq: Permission of Instructor
Acad Year 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Topics vary from year to year.
T. Colding

18.152 Introduction to Partial Differential Equations
Prereq: 18.100; 18.06, 18.700, or 18.701
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit H (except for Course 18 students)
Introduces three main types of partial differential equations: diffusion, elliptic, and hyperbolic. Includes mathematical tools, real-world examples and applications, such as the Black-Scholes equation, the European options problem, water waves, scalar conservation laws, first order equations and traffic problems.
W. Minicozzi

18.155 Differential Analysis
Prereq: 18.102 or 18.103
G (Fall)
3-0-9 H-LEVEL Grad Credit
18.156 Differential Analysis
Prereq: 18.155
G (Spring)
3-0-9 H-LEVEL Grad Credit
Fall: R. B. Melrose
Spring: L. Guth

18.157 Introduction to Microlocal Analysis
Prereq: 18.155
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
The semi-classical theory of partial differential equations. Discussion of Pseudodifferential operators, Fourier integral operators, asymptotic solutions of partial differential equations, and the spectral theory of Schroedinger operators from the semi-classical perspective. Heavy emphasis placed on the symplectic geometric underpinnings of this subject.
R. B. Melrose

18.158 Topics in Differential Equations
Prereq: 18.157
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Topics vary from year to year.
L. Saint-Raymond

18.175 Theory of Probability
Prereq: 18.100
G (Spring)
3-0-9 H-LEVEL Grad Credit
Sums of independent random variables, central limit phenomena, infinitely divisible laws, Levy processes, Brownian motion, conditioning, and martingales. Prior exposure to probability (e.g., 18.440) recommended.
V. Gorin

18.176 Stochastic Calculus
Prereq: 18.175
G (Spring)
3-0-9 H-LEVEL Grad Credit
A rigorous introduction to stochastic calculus. Topics include Brownian motion and continuous martingales, diffusions and Levy processes, Ito calculus, martingale representation and quadratic variation, Girsanov’s theorem, Bessel processes, general existence and uniqueness theory for stochastic differential equations, applications to partial differential equations, and a brief overview of applications to finance and statistical physics.
A. Guionnet

18.177 Topics in Stochastic Processes
Prereq: 18.175
G (Fall, Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Topics vary from year to year.
Fall: J. Miller
Spring: A. Guionnet

18.199 Graduate Analysis Seminar
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Studies original papers in differential analysis and differential equations. Intended for first- and second-year graduate students. Permission must be secured in advance.
V. W. Guillemin

18.238 Geometry and Quantum Field Theory
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
A rigorous introduction designed for mathematicians into perturbative quantum field theory, using the language of functional integrals. Basics of classical field theory. Free quantum theories. Feynman diagrams. Renormalization theory. Local operators. Operator product expansion. Renormalization group equation. The goal is to discuss, using mathematical language, a number of basic notions and results of QFT that are necessary to understand talks and papers in QFT and string theory.
Information: P. I. Etingof

18.276 Mathematical Methods in Physics
Prereq: 18.745 or some familiarity with Lie theory
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Content varies from year to year. Recent developments in quantum field theory require mathematical techniques not usually covered in standard graduate subjects.
V. G. Kac

APPLIED MATHEMATICS

18.303 Linear Partial Differential Equations: Analysis and Numerics
Prereq: 18.06 or 18.700
U (Fall)
3-0-9
Provides students with the basic analytical and computational tools of linear partial differential equations (PDEs) for practical applications in science and engineering, including heat/diffusion, wave, and Poisson equations. Analytics emphasize the viewpoint of linear algebra and
the analogy with finite matrix problems. Studies operator adjoints and eigenproblems, series solutions, Green’s functions, and separation of variables. Numerics focus on finite-difference and finite-element techniques to reduce PDEs to matrix problems, including stability and convergence analysis and implicit/explicit timestepping. MATLAB is introduced and used in homework for simple examples.

S. G. Johnson

18.304 Undergraduate Seminar in Discrete Mathematics
Prereq: 18.310 or 18.062; 18.06, 18.700, or 18.701; or permission of instructor
U (Fall, Spring)
3-0-9
Credit cannot also be received for 18.316

Seminar in combinatorics, graph theory, and discrete mathematics in general. Participants read and present papers from recent mathematics literature. Instruction and practice in written and oral communication provided. Enrollment limited.

Fall: P. Csikvari
Spring: J. Novak

18.305 Advanced Analytic Methods in Science and Engineering
Prereq: 18.04, 18.075, or 18.112
G (Fall)
3-0-9 H-LEVEL Grad Credit

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

18.306 Advanced Partial Differential Equations with Applications
Prereq: 18.03 or 18.034; 18.04, 18.075, or 18.112
G (Spring)
3-0-9 H-LEVEL Grad Credit


R. R. Rosales

18.310 Principles of Discrete Applied Mathematics
Prereq: Calculus II (GIR)
U (Fall)
4-0-11

Study of illustrative topics in discrete applied mathematics, including sorting algorithms, probability theory, information theory, coding theory, secret codes, generating functions, and linear programming. Instruction and practice in written and oral communication provided. Enrollment limited.

J. Fox, P. W. Shor

18.310A Principles of Discrete Applied Mathematics
Prereq: Calculus II (GIR)
U (Spring)
3-0-9
Credit cannot also be received for 18.310

Study of illustrative topics in discrete applied mathematics, including sorting algorithms, probability theory, information theory, coding theory, secret codes, generating functions, and linear programming.

M. X. Goemans

18.311 Principles of Continuum Applied Mathematics
Prereq: Calculus II (GIR); 18.03 or 18.034
U (Spring)
3-0-9

Covers fundamental concepts in continuous applied mathematics. Applications from traffic flow, fluids, elasticity, granular flows, etc. Also covers continuum limit; conservation laws, quasi-equilibrium; kinematic waves; characteristics, simple waves, shocks; diffusion (linear and nonlinear); numerical solution of wave equations; finite differences, consistency, stability; discrete and fast Fourier transforms; spectral methods; transforms and series (Fourier, Laplace). Additional topics may include sonic booms, Mach cone, caustics, lattices, dispersion and group velocity. Uses MATLAB computing environment.

R. R. Rosales

18.312 Algebraic Combinatorics
Prereq: 18.701 or 18.703
U (Spring)
3-0-9

Applications of algebra to combinatorics. Topics include walks in graphs, the Radon transform, groups acting on posets, Young tableaux, electrical networks.

P. Csikvari

18.314 Combinatorial Analysis
Prereq: Calculus II (GIR); 18.06, 18.700, or 18.701
U (Fall)
3-0-9

Combinatorial problems and methods for their solution. Enumeration, generating functions, recurrence relations, construction of bijections. Introduction to graph theory. Prior experience with abstraction and proofs is helpful.

R. P. Stanley

18.315 Combinatorial Theory
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year.

A. Postnikov

18.316 Seminar in Combinatorics
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Credit cannot also be received for 18.304

Content varies from year to year. Readings from current research papers in combinatorics. Topics to be chosen and presented by the class.

J. Fox

18.318 Topics in Combinatorics
Prereq: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics vary from year to year.

C. Lee

18.325 Topics in Applied Mathematics
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics vary from year to year.

L. Demanet
18.330 Introduction to Numerical Analysis
Prereq: Calculus II (GIR); 18.03 or 18.034
U (Spring)
3-0-9
H. Reid

18.335| Introduction to Numerical Methods
(Same subject as 6.337)
Prereq: 18.03 or 18.034; 18.06, 18.700, or 18.701
G (Spring)
3-0-9 H-LEVEL Grad Credit
Advanced introduction to numerical linear algebra and related numerical methods. Topics include direct and iterative methods for linear systems, eigenvalue and QR/SVD factorizations, stability and accuracy, floating-point arithmetic, sparse matrices, preconditioning, and the memory considerations underlying modern linear algebra software. Starting from iterative methods for linear systems, explores more general techniques for local and global nonlinear optimization, including quasi-Newton methods, trust regions, branch-and-bound, and multistart algorithms. Also addresses Chebyshev approximation and FFTs. MATLAB is introduced for problem sets.
S. G. Johnson

18.336| Fast Methods for Partial Differential and Integral Equations
(Same subject as 6.335)
Prereq: 6.336, 16.920, 18.085, 18.335, or permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
Unified introduction to the theory and practice of modern, near linear-time, numerical methods for large-scale partial-differential and integral equations. Topics include preconditioned iterative methods; generalized Fast Fourier Transform and other butterfly-based methods; multiresolution approaches, such as multigrid algorithms and hierarchical low-rank matrix decompositions; and low and high frequency Fast Multipole Methods. Example applications include aircraft design, cardiovascular system modeling, electronic structure computation, and tomographic imaging.
A. Townsend

18.337| Parallel Computing
(Same subject as 6.338)
Prereq: 18.06, 18.700, or 18.701
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Interdisciplinary introduction to parallel computing and modern big data analysis using Julia. Covers scientific computing topics such as dense and sparse linear algebra, N-body problems, and Fourier transforms, and geometric computing topics such as mesh generation and mesh partitioning. Focuses on application of these techniques to machine learning algorithms in big data applications. Provides direct experience with programming traditional-style supercomputing as well as working with modern cloud computing stacks. Designed to separate the realities and myths about the kinds of problems that can be solved on the world’s fastest machines.
A. Edelman

18.338 Eigenvalues of Random Matrices
Prereq: 18.701 or permission of instructor
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
Covers the modern main results of random matrix theory as it is currently applied in engineering and science. Topics include matrix calculus for finite and infinite matrices (e.g., Wigner’s semi-circle and Marcenko-Pastur laws), free probability, random graphs, combinatorial methods, matrix statistics, stochastic operators, passage to the continuum limit, moment methods, and compressed sensing. Knowledge of MATLAB helpful, but not required.
A. Edelman

18.352| Theoretical Environmental Analysis
(Same subject as 12.009)
Prereq: Physics I (GIR), Calculus II (GIR); Coreq: 18.03
U (Spring)
3-0-9
See description under subject 12.009.
D. H. Rothman

18.353| Nonlinear Dynamics: Chaos
(Same subject as 2.050J, 12.006)
Prereq: 18.03 or 18.034; Physics II (GIR)
U (Fall)
3-0-9
See description under subject 12.006.
R. Lagrange

18.354| Nonlinear Dynamics: Continuum Systems
(Same subject as 1.062J, 12.207J)
Prereq: 18.03 or 18.034; Physics II (GIR)
G (Spring)
3-0-9 H-LEVEL Grad Credit H (except for Course 18 students)
General mathematical principles of continuum systems. From microscopic to macroscopic descriptions in the form of linear or nonlinear (partial) differential equations. Exact solutions, dimensional analysis, calculus of variations and singular perturbation methods. Stability, waves and pattern formation in continuum systems. Subject matter illustrated using natural fluid and solid systems found, for example, in geophysics and biology.
J. Dunkel

18.355 Fluid Mechanics
Prereq: 18.354, 2.25, or 12.800
Acad Year 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
Topics include the development of Navier-Stokes equations, inviscid flows, boundary layers, lubrication theory, Stokes flows, and surface tension. Fundamental concepts illustrated through problems drawn from a variety of areas, including geophysics, biology, and the dynamics of sport. Particular emphasis on the interplay between dimensional analysis, scaling arguments, and theory. Includes classroom and laboratory demonstrations.
J. W. Bush

18.357 Interfacial Phenomena
Prereq: 18.354, 18.355, 12.800, 2.25, or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Fluid systems dominated by the influence of interfacial tension. Elucidates the roles of curvature pressure and Marangoni stress in a variety of hydrodynamic settings. Particular attention to drops and bubbles, soap films and minimal surfaces, wetting phenomena, water-repellency, surfactants, Marangoni flows, capillary origami and contact line dynamics. Theoretical developments are accompanied by classroom demonstrations. Highlights the role of surface tension in biology.
J. W. Bush
18.369 Mathematical Methods in Nanophotonics
Prereq: 18.305 or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit

High-level approaches to understanding complex optical media, structured on the scale of the wavelength, that are not generally analytically solvable. The basis for understanding optical phenomena such as photonic crystals and band gaps, anomalous diffraction, mechanisms for optical confinement, optical fibers (new and old), nonlinearities, and integrated optical devices. Methods covered include linear algebra and eigensystems for Maxwell's equations, symmetry groups and representation theory, Bloch's theorem, numerical eigensolver methods, time and frequency-domain computation, perturbation theory, and coupled-mode theories.

T. R. Akylas, R. R. Rosales

18.376 Wave Propagation
(Same subject as 1.138J, 2.062J)
Prereq: 2.003, 18.075
G (Spring)
3-0-9 H-LEVEL Grad Credit

See description under subject 2.062J.

T. R. Akylas, R. R. Rosales

18.377 Nonlinear Dynamics and Waves
(Same subject as 1.685J, 2.034J)
Prereq: Permission of instructor
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit

A unified treatment of nonlinear oscillations and wave phenomena with applications to mechanical, optical, geophysical, fluid, electrical and flow-structure interaction problems. Nonlinear free and forced vibrations; nonlinear resonances; self-excited oscillations; lock-in phenomena. Nonlinear dispersive and nondispersive waves; resonant wave interactions; propagation of wave pulses and nonlinear Schrodinger equation. Nonlinear long waves and breaking; theory of characteristics; the Korteweg-de Vries equation; solitons and solitary wave interactions. Stability of shear flows. Some topics and applications may vary from year to year.

T. R. Akylas, R. R. Rosales

18.384 Undergraduate Seminar in Physical Mathematics
Prereq: 18.311, 18.353, 18.354, or permission of instructor
U (Fall)
3-0-9

Covers the mathematical modeling of physical systems, with emphasis on the reading and presentation of papers. Addresses a broad range of topics, with particular focus on macroscopic physics and continuum systems: fluid dynamics, solid mechanics, and biophysics. Instruction and practice in written and oral communication provided. Enrollment limited.

P.-T. Brun

18.385 Nonlinear Dynamics and Chaos 
(Same subject as 2.036J)
Prereq: 18.03 or 18.034
Acad Year 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit


R. R. Rosales

18.386 Advanced Nonlinear Dynamics and Chaos
Prereq: 18.385 or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit


Information: R. R. Rosales

18.389 Group Theory with Applications to Physics
Prereq: 8.321
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit

Selection of topics from the theory of finite groups, Lie groups, and group representations, motivated by quantum mechanics and particle physics. 8.322 and 8.323 helpful.

D. Z. Freedman

18.396 Supersymmetric Quantum Field Theories
(Same subject as 8.831J)
Prereq: Permission of instructor
Acad Year 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics selected from the following: SUSY algebras and their particle representations; Weyl and Majorana spinors; Lagrangians of basic four-dimensional SUSY theories, both rigid SUSY and supergravity; supermultiplets of fields and superspace methods; renormalization properties, and the non-renormalization theorem; spontaneous breakdown of SUSY; and phenomenological SUSY theories. Some prior knowledge of Noether's theorem, derivation and use of Feynman rules, I-loop renormalization, and gauge theories is essential.

D. Z. Freedman

18.398 Quantum Field Theories
Prereq: Permission of instructor
G (Spring)

Not offered regularly; consult department
3-0-9 H-LEVEL Grad Credit

For students who want to have a clear understanding of quantum field theories. Appropriate for students who have not taken such a subject as well as students who have but are not entirely comfortable with the basic concepts and techniques. The topics begin with classical mechanics and end with gauge field theories and the renormalization of the standard model.

Information: H. Cheng
18.400J Automata, Computability, and Complexity
(Same subject as 6.045J)
Prereq: 6.042
U (Spring)
4-0-8
See description under subject 6.045J.
A. Moitra

18.404J Theory of Computation
(Same subject as 6.840J)
Prereq: 18.310 or 18.062J
G (Fall)
4-0-8 H-LEVEL Grad Credit (except for Course 18 students)
A more extensive and theoretical treatment of the material in 6.045J/18.400J, emphasizing computability and computational complexity theory. Regular and context-free languages. Decidable and undecidable problems, reducibility, recursive function theory. Time and space measures on computation, completeness, hierarchy theorems, inherently complex problems, oracles, probabilistic computation, and interactive proof systems.
M. Sipser

18.405J Advanced Complexity Theory
(Same subject as 6.841J)
Prereq: 18.404
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
D. Moshkovitz

18.409 Topics in Theoretical Computer Science
Prereq: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Study of areas of current interest in theoretical computer science. Topics vary from term to term.
A. Moitra

18.410J Design and Analysis of Algorithms
(Same subject as 6.046J)
Prereq: 6.006
U (Fall, Spring)
4-0-8
See description under subject 6.046J.
E. Demaine, M. Goemans

18.415J Advanced Algorithms
(Same subject as 6.854J)
Prereq: 6.041, 6.042, or 18.440; 6.046
G (Fall)
5-0-7 H-LEVEL Grad Credit
See description under subject 6.854J.
D. R. Karger

18.416J Randomized Algorithms
(Same subject as 6.856J)
Prereq: 6.854J, 6.041 or 6.042J
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
5-0-7 H-LEVEL Grad Credit
See description under subject 6.856J.
D. R. Karger

18.417 Introduction to Computational Molecular Biology
Prereq: 6.01, 6.006, or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Introduces basic computational methods used to model and predict the structure of biomolecules (proteins, DNA, RNA). Covers classical techniques in the field (molecular dynamics, Monte Carlo, dynamic programming) to more recent advances in analyzing and predicting RNA and protein structure, including data compression, Shannon’s Theorem, and error-correcting codes. Students present and discuss the subject matter. Instruction and practice in written and oral communication provided. Enrollment limited.
P. W. Shor

18.425J Cryptography and Cryptanalysis
(Same subject as 6.875J)
Prereq: 6.046J
G (Spring)
3-0-9 H-LEVEL Grad Credit
See description under subject 6.875J.
S. Goldwasser, S. Micali

18.426J Advanced Topics in Cryptography
(Same subject as 6.876J)
Prereq: 6.875
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
See description under subject 6.876J.
S. Goldwasser, S. Micali

18.433 Combinatorial Optimization
Prereq: 18.06, 18.700, or 18.701
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit (except for Course 18 students)
Thorough treatment of linear programming and combinatorial optimization. Topics include matching theory, network flow, matroid optimization, and how to deal with NP-hard optimization problems. Prior exposure to discrete mathematics (such as 18.310) helpful.
M. X. Goemans
18.434 Seminar in Theoretical Computer Science
Prereq: 18.410
U (Spring)
3-0-9
Topics vary from year to year. Students present and discuss the subject matter. Instruction and practice in written and oral communication provided. Enrollment limited.
R. Peng

18.435J Quantum Computation
(Same subject as 2.111J, 8.370J)
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
Provides an introduction to the theory and practice of quantum computation. Topics covered: physics of information processing; quantum algorithms including the factoring algorithm and Grover’s search algorithm; quantum error correction; quantum communication and cryptography. Knowledge of quantum mechanics helpful but not required.
I. Chuang, E. Farhi, S. Lloyd, P. W. Shor

18.436j Quantum Information Science
(Same subject as 6.443J, 8.371J)
Prereq: 18.435
G (Spring, Summer)
3-0-9 H-LEVEL Grad Credit
See description under subject 8.371J.
Information: P. W. Shor

18.437J Distributed Algorithms
(Same subject as 6.852J)
Prereq: 6.046
G (Fall)
3-0-9 H-LEVEL Grad Credit
See description under subject 6.852J.
N. A. Lynch

18.438 Advanced Combinatorial Optimization
Prereq: 18.433 or permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
Advanced treatment of combinatorial optimization with an emphasis on combinatorial aspects. Non-bipartite matchings, submodular functions, matroid intersection/union, matroid matching, submodular flows, multicommodity flows, packing and connectivity problems, and other recent developments.
M. X. Goemans

18.440 Probability and Random Variables
Prereq: Calculus II (GIR)
U (Fall, Spring)
3-0-9 REST
Credit cannot also be received for 6.041, 6.431
Fall: A. Guionnet
Spring: J. A. Kelner

18.443 Statistics for Applications
Prereq: 18.440 or 6.041
G (Fall, Spring)
3-0-9 H-LEVEL Grad Credit H (except for Course 18 students)
A broad treatment of statistics, concentrating on specific statistical techniques used in science and industry. Topics: hypothesis testing and estimation. Confidence intervals, chi-square tests, nonparametric statistics, analysis of variance, regression, correlation, decision theory, and Bayesian statistics.
Fall: R. M. Dudley
Spring: P. Kempthorne

18.445 Introduction to Stochastic Processes
Prereq: 18.440 or 6.041
G (Spring)
3-0-9 H-LEVEL Grad Credit
H. Wu

18.465 Topics in Statistics
Prereq: Permission of instructor
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Topics vary from term to term.
R. M. Dudley

18.466 Mathematical Statistics
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
Decision theory, estimation, confidence intervals, hypothesis testing. Introduces large sample theory. Asymptotic efficiency of estimates. Exponential families. Sequential analysis.
P. Kempthorne

18.472 Topics in Mathematics with Applications in Finance (New)
Prereq: 18.03; 18.06; 18.05 or 18.440
U (Fall)
3-0-9
Introduction to mathematical concepts and techniques used in finance. Lectures focusing on linear algebra, probability, statistics, stochastic processes, and numerical methods are interspersed with lectures by financial sector professionals illustrating the corresponding application in the industry. Prior knowledge of economics or finance helpful but not required.
P. Kempthorne, V. Strela, J. Xia

For additional related subjects in statistics, see:
Civil and Environmental Engineering: 1.151, 1.155, 1.202J, 1.203J, 1.205J
Electrical Engineering and Computer Science:
6.041, 6.231, 6.245, 6.262, 6.431, 6.432, and 6.435
Management: 15.034, 15.061, 15.065, 15.070, 15.075, 15.076, 15.098, and 15.306
Mathematics: 18.05, 18.175, 18.176, 18.177, 18.440, 18.443, 18.445, 18.465, 18.466, and 18.472
See also: 2.061, 2.830, 5.70, 5.72, 7.02, 8.044, 8.08, 10.816, 11.220, 11.221, 16.322, 17.872, 17.874, 22.38, HST.191, and MAS.622J.

LOGIC

18.504 Seminar in Logic
Prereq: 18.100; 18.06, 18.510, 18.511, 18.700, or 18.701
Acad Year 2014–2015: U (Spring)
Acad Year 2015–2016: Not offered
3-0-9
Students present and discuss the subject matter taken from current journals or books. Topics vary from year to year. Instruction and practice in written and oral communication provided. Enrollment limited.
H. Cohn
18.510 Introduction to Mathematical Logic and Set Theory
Prereq: None
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Fall) 3-0-9

Axiom of choice and transfinite induction.
Elementary model theory: completeness, compactness, and Lowenheim-Skolem theorems.
Godel’s incompleteness theorem.
H. Cohn

18.511 Introduction to Computability and Undecidability
Prereq: None
U (Fall)
Not offered regularly; consult department 3-0-9

Church’s thesis and models of computation. Elementary computability theory: enumeration and recursion theorems, the halting problem, relative computability, Turing degrees, and basic priority constructions. Post’s problem. Truth vs. provability, Godel’s incompleteness theorem. Decidable and undecidable problems in number theory and other areas of mathematics.
Information: B. Poonen

18.515 Mathematical Logic
Prereq: Permission of instructor G (Spring)
Not offered regularly; consult department 3-0-9 H-LEVEL Grad Credit

Information: B. Poonen

ALGEBRA AND NUMBER THEORY

18.700 Linear Algebra
Prereq: Calculus II (GIR) U (Fall) 3-0-9 REST
Credit cannot also be received for 18.06
Vector spaces, systems of linear equations, bases, linear independence, matrices, determinants, eigenvalues, inner products, quadratic forms, and canonical forms of matrices. More emphasis on theory and proofs than in 18.06.
D. A. Vogan

18.701 Algebra I
Prereq: 18.100 or permission of instructor U (Fall) 3-0-9

18.702 Algebra II
Prereq: 18.701 U (Spring) 3-0-9

More extensive and theoretical than the 18.700-18.703 sequence. Experience with proofs necessary. First term: group theory, geometry, and linear algebra. Second term: group representations, rings, ideals, fields, polynomial rings, modules, factorization, integers in quadratic number fields, field extensions, Galois theory.
M. Artin

18.703 Modern Algebra
Prereq: Calculus II (GIR) U (Spring) 3-0-9

Focuses on traditional algebra topics that have found greatest application in science and engineering as well as in mathematics: group theory, emphasizing finite groups; ring theory, including ideals and unique factorization in polynomial and Euclidean rings; field theory, including properties and applications of finite fields. 18.700 and 18.703 together form a standard algebra sequence.
V. G. Kac

18.704 Seminar in Algebra
Prereq: 18.701; or 18.06, 18.703; or 18.700, 18.703 U (Spring) 3-0-9

Topics vary from year to year. Students present and discuss the subject matter. Instruction and practice in written and oral communication provided. Some experience with proofs required. Enrollment limited.
C. Walton

18.705 Commutative Algebra
Prereq: 18.702 G (Fall) 3-0-9 H-LEVEL Grad Credit

Exactness, direct limits, tensor products, Cayley-Hamilton theorem, integral dependence, localization, Cohen-Seidenberg theory, Noether normalization, Nullstellensatz, chain conditions, primary decomposition, length, Hilbert func-
tions, dimension theory, completion, Dedekind domains.
Y. Liu

18.706 Noncommutative Algebra
Prereq: 18.705
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring) 3-0-9 H-LEVEL Grad Credit

Topics may include representations of quivers, Wedderburn theory, Morita equivalence, localization and Goldie’s theorem, central simple algebras and the Brauer group, maximal orders, representations, polynomial identity rings, invariant theory growth of algebras, Gelfand-Kirillov dimension.
G. Lusztig

18.715 Introduction to Representation Theory (18.712)
Prereq: 18.702 or 18.703
Acad Year 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered 3-0-9 H-LEVEL Grad Credit

P. I. Etingof

18.721 Introduction to Algebraic Geometry
Prereq: 18.702, 18.901
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Spring) 3-0-9

Presents basic examples of complex algebraic varieties, affine and projective algebraic geometry, sheaves, cohomology.
M. Artin

18.725 Algebraic Geometry I
Prereq: None. Coreq: 18.705
G (Fall) 3-0-9 H-LEVEL Grad Credit

Introduces the basic notions and techniques of modern algebraic geometry. Covers fundamental notions and results about algebraic varieties over an algebraically closed field; relations between complex algebraic varieties and complex analytic varieties; and examples with emphasis on algebraic curves and surfaces. Introduction to the language of schemes and properties of morphisms. Knowledge of elementary algebraic topology, elementary differential geometry recommended, but not required.
T. Schlank
18.726 Algebraic Geometry II
Prereq: 18.725
G (Spring)
3-0-9 H-LEVEL Grad Credit

Continuation of the introduction to algebraic geometry given in 18.725. More advanced properties of the varieties and morphisms of schemes, as well as sheaf cohomology.
R. Bezrukavnikov

18.727 Topics in Algebraic Geometry
Prereq: 18.725
G (Fall)
Not offered regularly; consult department
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Topics vary from year to year.
Information: V. G. Kac

18.735 Topics in Algebra
Prereq: 18.705
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Topics vary from year to year.
R. Bezrukavnikov

18.737 Algebraic Groups
Prereq: 18.705
Acad Year 2014–2015: G (Fall)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit

Structure of linear algebraic groups over an algebraically closed field, with emphasis on reductive groups. Representations of groups over a finite field using methods from étale cohomology. Some results from algebraic geometry are stated without proof.
F. Charles

18.739 Theory of Invariants
Prereq: 18.705
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit

Information: V. G. Kac

18.745 Introduction to Lie Algebras
Prereq: 18.701 or 18.703
G (Spring)
3-0-9 H-LEVEL Grad Credit

Topics may include structure of finite-dimensional Lie algebras; theorems of Engel and Lie; Cartan subalgebras and regular elements; trace form and Cartan’s criterion; Chevalley’s conjugacy theorem; classification and construction of semisimple Lie algebras; Weyl group; universal enveloping algebra and the Casimir operator; Weyl’s complete reducibility theorem, Levi and Mal’tsev theorems; Verma modules; classification of irreducible finite-dimensional representations of semisimple Lie algebras; Weyl’s character and dimension formulas.
D. A. Vogan

18.747 Infinite-dimensional Lie Algebras
Prereq: 18.745
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit

Topics vary from year to year.
P. I. Etingof

18.755 Introduction to Lie Groups
Prereq: 18.100; 18.700 or 18.701
G (Fall)
3-0-9 H-LEVEL Grad Credit

A general introduction to manifolds and Lie groups. The role of Lie groups in mathematics and physics. Exponential mapping. Correspondence with Lie algebras. Homogeneous spaces and transformation groups. Adjoint representation. Coveting groups. Automorphism groups. Invariant differential forms and cohomology of Lie groups and homogeneous spaces. 18.101 recommended but not required.
D. A. Vogan

18.757 Representations of Lie Groups
Prereq: 18.745 or 18.755
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit

Covers representations of locally compact groups, with emphasis on compact groups and abelian groups. Includes Peter-Weyl theorem and Cartan-Weyl highest weight theory for compact Lie groups.
D. A. Vogan

18.758 Representations of Lie Groups
Prereq: 18.745
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit

Introduction to unitary representations of semisimple Lie groups: compact groups and the Borel-Weil theorem; parabolic induction; Zuckerman construction; unipotent representations.
D. A. Vogan

18.769 Topics in Lie Theory
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Topics vary from year to year.
P. I. Etingof

18.781 Theory of Numbers
Prereq: None
U (Spring)
3-0-9

An elementary introduction to number theory with no algebraic prerequisites. Primes, congruences, quadratic reciprocity, diophantine equations, irrational numbers, continued fractions, partitions.
J.-L. Kim

18.782 Introduction to Arithmetic Geometry
Prereq: 18.702
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: U (Fall)
3-0-9

Introduction to arithmetic geometry, motivated by the problem of finding rational points on curves. Exposes students to p-adic numbers and some fundamental results from number theory and algebraic geometry, such as the Hasse-Minkowski theorem and the Riemann-Roch theorem for curves. Additional topics may include Mordell’s theorem, the Weil conjectures, and Jacobian varieties.
A. Sutherland

18.783 Elliptic Curves
Prereq: None. Coreq: 18.702, 18.703, or permission of instructor
Acad Year 2014–2015: G (Spring)
Acad Year 2015–2016: Not offered
3-0-9 H-LEVEL Grad Credit (except for Course 18 students)

Computationally focused introduction to elliptic curves, with applications to number theory and cryptography. Topics include point-counting.
isogenies, pairings, and the theory of complex multiplication, with applications to integer factorization, primality proving, and elliptic curve cryptography. Includes a brief introduction to modular curves and the proof of Fermat’s Last Theorem.

A. Sutherland

18.784 Seminar in Number Theory
Prereq: 18.06, 18.100
U (Fall)
3-0-9
Topics vary from year to year. Students present and discuss the subject matter. Instruction and practice in written and oral communication provided. Enrollment limited.

V. G. Kac

18.785 Number Theory I
Prereq: 18.112, 18.702
G (Fall)
3-0-9 H-LEVEL Grad Credit
Dedekind domains, unique factorization of ideals, splitting of primes. Lattice methods, finiteness of the class group, Dirichlet’s unit theorem. Local fields, ramification, discriminants. Zeta and L-functions, analytic class number formula. Adèles and ideles. Statements of class field theory and the Chebotarev density theorem.

B. Poonen

18.786 Number Theory II
Prereq: 18.785
G (Spring)
3-0-9 H-LEVEL Grad Credit
Continuation of 18.785. More advanced topics in number theory, such as Galois cohomology, proofs of class field theory, modular forms and automorphic forms, Galois representations, or quadratic forms.

B. Poonen

18.787 Topics in Number Theory
Prereq: Permission of instructor
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Topics vary from year to year.

B. Poonen

18.821 Project Laboratory in Mathematics
Prereq: Two mathematics subjects numbered 18.100 or above
U (Fall, Spring)
3-6-3 Institute LAB
Guided research in mathematics, employing the scientific method. Students confront puzzling and complex mathematical situations, through the acquisition of data by computer, pencil and paper, or physical experimentation, and attempt to explain them mathematically. Students choose three projects from a large collection of options. Each project results in a laboratory report subject to revision; oral presentation on one or two projects. Projects drawn from many areas, including dynamical systems, number theory, algebra, fluid mechanics, asymptotic analysis, knot theory, and probability. Enrollment limited.

Fell: D. Jerison
Spring: C. Barwick

18.901 Introduction to Topology
Prereq: 18.100 or permission of instructor
G (Fall, Spring)
3-0-9 H-LEVEL Grad Credit H (except for Course 18 students)
Introduces topology, covering topics fundamental to modern analysis and geometry. Topological spaces and continuous functions, connectedness, compactness, separation axioms, and selected further topics such as function spaces, embedding theorems, dimension theory, or covering spaces and the fundamental group.
Fall: J. R. Munkres
Spring: E. Dotto

18.904 Seminar in Topology
Prereq: 18.901
U (Spring)
3-0-9
Topics vary from year to year and include the fundamental group and covering spaces. Time permitting, also covers the relationship between these objects and the theory of knots. Students present and discuss the subject matter. Instruction and practice in written and oral communication provided. Enrollment limited.

G. Tabuada

18.905 Algebraic Topology I
Prereq: 18.701 or 18.703; 18.901
G (Fall)
3-0-9 H-LEVEL Grad Credit
Singular homology, CW complexes, universal coefficient and Künneth theorems, cohomology, cup products, Poincare duality.

G. Tabuada

18.906 Algebraic Topology II
Prereq: 18.905
G (Spring)
3-0-9 H-LEVEL Grad Credit
Continues the introduction to Algebraic Topology from 18.905. Topics include basic homotopy theory, spectral sequences, characteristic classes, and cohomology operations.

H. R. Miller

18.915 Graduate Topology Seminar
Prereq: 18.906
G (Fall)
3-0-9 H-LEVEL Grad Credit
Study and discussion of important original papers in the various parts of algebraic topology. Open to all students who have taken 18.906 or the equivalent, not only prospective topologists.

H. R. Miller

18.917 Topics in Algebraic Topology
Prereq: 18.906
G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Content varies from year to year. Introduces new and significant developments in algebraic topology with the focus on homotopy theory and related areas.

C. Barwick

18.937 Topics in Geometric Topology
Prereq: Permission of instructor
G (Fall)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit
Content varies from year to year. Introduces new and significant developments in geometric topology.

T. Mrowka
18.950 Differential Geometry
Prereq: 18.100; 18.06, 18.700, or 18.701
G (Spring)
3-0-9 H-LEVEL Grad Credit (except for Course 18 students)

Introduction to differential geometry, centered on notions of curvature. Starts with curves in the plane, and proceeds to higher dimensional submanifolds. Computations in coordinate charts: first and second fundamental form, Christoffel symbols. Discusses the distinction between extrinsic and intrinsic aspects, in particular Gauss’ theorema egregium. The Gauss-Bonnet theorem.

Geodesics. Examples such as hyperbolic space.
T. Colding

18.952 Theory of Differential Forms
Prereq: 18.101; 18.700 or 18.701
U (Spring)
3-0-9

Multilinear algebra: tensors and exterior forms. Differential forms on $\mathbb{R}^n$: exterior differentiation, the pull-back operation and the Poincare lemma. Applications to physics: Maxwell’s equations from the differential form perspective. Integration of forms on open sets of $\mathbb{R}^n$. The change of variables formula revisited. The degree of a differentiable mapping. Differential forms on manifolds and De Rham theory. Integration of forms on manifolds and Stokes’ theorem. The push-forward operation for forms. Thom forms and intersection theory. Applications to differential topology.

V. W. Guillemin

18.965 Geometry of Manifolds I
Prereq: 18.101, 18.950 or 18.952
G (Fall)
3-0-9 H-LEVEL Grad Credit

18.966 Geometry of Manifolds II
Prereq: 18.965
G (Spring)
3-0-9 H-LEVEL Grad Credit

Differential forms, introduction to Lie groups, the DeRham theorem, Riemannian manifolds, curvature, the Hodge theory. 18.966 is a continuation of 18.965 and focuses more deeply on various aspects of the geometry of manifolds. Contents vary from year to year, and can range from Riemannian geometry (curvature, holonomy) to symplectic geometry, complex geometry and Hodge-Kahler theory, or smooth manifold topology. Prior exposure to calculus on manifolds, as in 18.952, is recommended.

Fall: E. Murphy
Spring: T. Colding

18.969 Topics in Geometry
Prereq: 18.965
Acad Year 2014–2015: Not offered
Acad Year 2015–2016: G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year.
W. Minicozzi

18.979 Graduate Geometry Seminar
Prereq: Permission of instructor
G (Spring)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year. Study of classical papers in geometry and in applications of analysis to geometry and topology.
T. Mrowka

18.994 Seminar in Geometry
Prereq: 18.101, 18.102, 18.103, or 18.112
U (Fall)
3-0-9

Students present and discuss subject matter taken from current journals or books. Topics vary from year to year. Instruction and practice in written and oral communication provided.
J. Lauer

18.999 Research in Mathematics
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged
Can be repeated for credit

Opportunity for study of graduate-level topics in mathematics under the supervision of a member of the department. For graduate students desiring advanced work not provided in regular subjects.

Information: A. Borodin, W. Minicozzi

18.THG Graduate Thesis
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Program of research leading to the writing of a PhD thesis; to be arranged by the student and an appropriate MIT faculty member.
Information: A. Borodin, W. Minicozzi

18.S096 Special Subject in Mathematics
Prereq: Permission of instructor
U (IAP, Spring)
Units arranged
Can be repeated for credit

18.S097 Special Subject in Mathematics
Prereq: Permission of instructor
U (IAP, Spring)
Units arranged [P/D/F]
Can be repeated for credit

Opportunity for group study of subjects in mathematics not otherwise included in the curriculum. Offerings are initiated by members of the Mathematics faculty on an ad hoc basis, subject to departmental approval. 18.S097 is graded P/D/F.

Information: G. Staffilani

18.599–18.5998 Special Subject in Mathematics
Prereq: Permission of instructor
G (Fall, IAP, Spring)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Opportunity for group study of advanced subjects in mathematics not otherwise included in the curriculum. Offerings are initiated by members of the Mathematics faculty on an ad hoc basis, subject to Departmental approval.

Information: G. Staffilani

Information: G. Staffilani

18.UR Undergraduate Research
Prereq: Permission of instructor
U (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit

Undergraduate research opportunities in mathematics. Permission required in advance to register for this subject. For further information, consult the departmental coordinator.

Information: G. Staffilani
**Bachelor of Science in Mathematics/Course 18**

<table>
<thead>
<tr>
<th>General Institute Requirements (GI�s)</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Requirement</td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement (one subject can be satisfied by 18.03 or 18.034 in the Departmental Program)</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total GIR Subjects Required for SB Degree</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Communication Requirement</th>
</tr>
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<tbody>
<tr>
<td>The program includes a Communication Requirement of 4 subjects: 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and 2 subjects designated as Communication Intensive in the Major (CI-M).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLUS Departmental Program</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required Subjects</strong></td>
<td></td>
</tr>
<tr>
<td>One of the following two subjects:</td>
<td>12</td>
</tr>
<tr>
<td>18.03 or 18.034 Differential Equations, 12, REST; Calculus II (GI영상)</td>
<td></td>
</tr>
<tr>
<td><strong>Restricted Electives</strong></td>
<td>96–102</td>
</tr>
<tr>
<td>To satisfy the requirements that students take two CI-M subjects, students must take two of the following subjects: 18.104, 18.304, 18.384, 18.424, 18.434, 18.504, 18.704, 18.784, 18.821, 18.904, or 18.994</td>
<td></td>
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<tr>
<td>or one from the above list and one of the following subjects: 8.06, 14.33, 18.100C, or 18.310</td>
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<tr>
<td><strong>General Mathematics Option</strong></td>
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<tr>
<td>Eight 12-unit subjects of essentially different content, including at least six advanced subjects (first decimal digit one or higher). One of these eight subjects must be 18.06, 18.700, or 18.701.</td>
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<tr>
<td><strong>Applied Mathematics Option</strong></td>
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</tr>
<tr>
<td>18.310A Principles of Discrete Applied Mathematics, 12; Calculus II (GI영상) or 18.310 Principles of Discrete Applied Mathematics, 15, CI-M; Calculus II (GI영상)</td>
<td></td>
</tr>
<tr>
<td>18.311 Principles of Continuum Applied Mathematics, 12; Calculus II (GI영상), 18.03*</td>
<td></td>
</tr>
<tr>
<td>One of the following two subjects:</td>
<td></td>
</tr>
<tr>
<td>18.04 Complex Variables with Applications, 12; Calculus II (GI영상), 18.03*</td>
<td></td>
</tr>
<tr>
<td>18.112 Functions of a Complex Variable, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>One of the following two subjects:</td>
<td></td>
</tr>
<tr>
<td>18.06 Linear Algebra, 12, REST; Calculus II (GI영상)</td>
<td></td>
</tr>
<tr>
<td>18.700 Linear Algebra, 12, REST; Calculus II (GI영상)</td>
<td></td>
</tr>
<tr>
<td><strong>Four additional 12-unit Course 18 subjects from the following two groups with at least one subject from each group:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Group I</strong>—Probability and statistics, combinatorics, computer science</td>
<td></td>
</tr>
<tr>
<td>18.100 Real Analysis, 12; Calculus II (GI영상)*</td>
<td></td>
</tr>
<tr>
<td>18.701 Algebra I, 12; 18.100*</td>
<td></td>
</tr>
<tr>
<td>18.702 Algebra II, 12; 18.701</td>
<td></td>
</tr>
<tr>
<td>18.901 Introduction to Topology, 12; 18.100*</td>
<td></td>
</tr>
<tr>
<td>One of the following subjects:</td>
<td></td>
</tr>
<tr>
<td>18.101 Analysis and Manifolds, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>18.102 Introduction to Functional Analysis, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>18.103 Fourier Analysis—Theory and Applications, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>An undergraduate seminar from the following list: 18.104, 18.504, 18.704, 18.784, 18.904, 18.994 (12 units).</td>
<td></td>
</tr>
<tr>
<td>Two additional 12-unit Course 18 subjects of essentially different content, with the first decimal digit one or higher (24 units)</td>
<td></td>
</tr>
<tr>
<td><strong>Theoretical Mathematics Option</strong></td>
<td></td>
</tr>
<tr>
<td>18.100 Real Analysis, 12; Calculus II (GI영상)*</td>
<td></td>
</tr>
<tr>
<td>18.701 Algebra I, 12; 18.100*</td>
<td></td>
</tr>
<tr>
<td>18.702 Algebra II, 12; 18.701</td>
<td></td>
</tr>
<tr>
<td>18.901 Introduction to Topology, 12; 18.100*</td>
<td></td>
</tr>
<tr>
<td>One of the following subjects:</td>
<td></td>
</tr>
<tr>
<td>18.101 Analysis and Manifolds, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>18.102 Introduction to Functional Analysis, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>18.103 Fourier Analysis—Theory and Applications, 12; 18.100, 18.06*</td>
<td></td>
</tr>
<tr>
<td>An undergraduate seminar from the following list: 18.104, 18.504, 18.704, 18.784, 18.904, 18.994 (12 units).</td>
<td></td>
</tr>
<tr>
<td>Two additional 12-unit Course 18 subjects of essentially different content, with the first decimal digit one or higher (24 units)</td>
<td></td>
</tr>
<tr>
<td><strong>Departmental Program Units That Also Satisfy the GI�s</strong></td>
<td>(12)</td>
</tr>
<tr>
<td><strong>Unrestricted Electives</strong></td>
<td>78–84</td>
</tr>
<tr>
<td><strong>Total Units Beyond the GI�s Required for SB Degree</strong></td>
<td>180</td>
</tr>
</tbody>
</table>

No subject can be counted both as part of the 17-subject GI�s and as part of the 180 units required beyond the GI�s. Every subject in the student’s departmental program will count toward one or the other, but not both.

**Notes**

*Alternate prerequisites and corequisites are listed in the subject description.

(1) Students may substitute one of the more advanced subjects 18.152 Introduction to Partial Differential Equations or 18.303 Linear Partial Differential Equations: Analysis and Numerics for 18.03.

(2) Students may substitute the more advanced subject 18.701 Algebra I.

(3) A list of acceptable subjects is available from Math Academic Services and on the Mathematics Department website.

For an explanation of credit units, or hours, please refer to the online help of the MIT Subject Listing & Schedule, [http://student.mit.edu/catalog/index.cgi](http://student.mit.edu/catalog/index.cgi).
# Bachelor of Science in Mathematics with Computer Science/Course 18-C

## General Institute Requirements (GIRs)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Science Requirement</strong></td>
<td>6</td>
</tr>
<tr>
<td>Humanities, Arts, and Social Sciences Requirement</td>
<td>8</td>
</tr>
<tr>
<td>Restricted Electives in Science and Technology (REST) Requirement</td>
<td>2</td>
</tr>
<tr>
<td>Laboratory Requirement</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total GIR Subjects Required for SB Degree**: 17

## Communication Requirement

The program includes a Communication Requirement of 4 subjects:

- 2 subjects designated as Communication Intensive in Humanities, Arts, and Social Sciences (CI-H); and
- 2 subjects designated as Communication Intensive in the Major (CI-M).

## PLUS Departmental Program

**Subject names below are followed by credit units, and by prerequisites, if any (corequisites in italics).**

### Required Subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.03 or 18.034 Differential Equations, 12 †</td>
<td></td>
</tr>
<tr>
<td>18.06 or 18.700 Linear Algebra, 12, 12 REST</td>
<td></td>
</tr>
<tr>
<td>18.400 Design and Analysis of Algorithms, 12</td>
<td></td>
</tr>
<tr>
<td>6.006 Introduction to EECS I, 12, 1/2 LAB</td>
<td></td>
</tr>
<tr>
<td>6.006 Introduction to Algorithms, 12, 6.01</td>
<td></td>
</tr>
</tbody>
</table>

**One subject from each of the following three groups:**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.062 Mathematics for Computer Science, 12, REST; Calculus I (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.310 Principles of Discrete Applied Mathematics, 12; Calculus II (GIR)</td>
<td></td>
</tr>
<tr>
<td>18.400 Automata, Computability, and Complexity, 12; 18.062</td>
<td></td>
</tr>
<tr>
<td>18.404 Theory of Computation, 12; 18.062*</td>
<td></td>
</tr>
<tr>
<td>6.005 Elements of Software Construction, 12; 6.01, 18.062*</td>
<td></td>
</tr>
<tr>
<td>6.033 Computer System Engineering, 12; 6.004, 6.02</td>
<td></td>
</tr>
</tbody>
</table>

## Restricted Electives

4 additional 12-unit subjects from Course 18 and one additional subject of at least 12 units from Course 6.

### Departmental Program Units That Also Satisfy the GIRs

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(24)</td>
</tr>
</tbody>
</table>

## Unrestricted Electives

48

**Total Units Beyond the GIRs Required for SB Degree**: 180–186

*No subject can be counted both as part of the 17-subject GIRs and as part of the 180 units required beyond the GIRs. Every subject in the student’s departmental program will count toward one or the other, but not both.*

### Notes

- *Alternate prerequisites and corequisites are listed in the subject description.
- † Students may substitute one of the more advanced subjects 18.152 Introduction to Partial Differential Equations or 18.703 Linear Partial Differential Equations: Analysis and Numerics for 18.03.
- ‡ Students may substitute the more advanced subject 18.701 Algebra 1.
- *Recommended alternative.

For an explanation of credit units, or hours, please refer to the online help in the MIT Subject Listing & Schedule, [http://student.mit.edu/catalog/index.cgi](http://student.mit.edu/catalog/index.cgi).