DEPARTMENT OF MATHEMATICS

The Department of Mathematics (*http://math.mit.edu*) offers training at the undergraduate, graduate, and postgraduate levels. Its expertise covers a broad spectrum of fields ranging from the traditional areas of "pure" mathematics, such as analysis, algebra, geometry, and topology, to applied mathematics areas such as combinatorics, computational biology, fluid dynamics, theoretical computer science, and theoretical physics.

Course 18 includes two undergraduate degrees: a Bachelor of Science in Mathematics and a Bachelor of Science in Mathematics with Computer Science. Undergraduate students may choose one of three options leading to the Bachelor of Science in Mathematics: applied mathematics, pure mathematics, or general mathematics. The general mathematics option provides a great deal of flexibility and allows students to design their own programs in conjunction with their advisors. The Mathematics with Computer Science degree is offered for students who want to pursue interests in mathematics and theoretical computer science within a single undergraduate program.

At the graduate level, the Mathematics Department offers the PhD in Mathematics, which culminates in the exposition of original research in a dissertation. Graduate students also receive training and gain experience in the teaching of mathematics.

The CLE Moore instructorships and Applied Mathematics instructorships bring mathematicians at the postdoctoral level to MIT and provide them with training in research and teaching.

Undergraduate Study

An undergraduate degree in mathematics provides an excellent basis for graduate work in mathematics or computer science, or for employment in such fields as finance, business, or consulting. Students' programs are arranged through consultation with their faculty advisors.

Undergraduates in mathematics are encouraged to elect an undergraduate seminar during their junior or senior year. The experience gained from active participation in a seminar conducted by a research mathematician has proven to be valuable for students planning to pursue graduate work as well as for those going on to other careers. These seminars also provide training in the verbal and written communication of mathematics and may be used to fulfill the Communication Requirement.

Many mathematics majors take 18.821 Project Laboratory in Mathematics, which fulfills the Institute's Laboratory Requirement and counts toward the Communication Requirement.

Bachelor of Science in Mathematics (Course 18)

General Mathematics Option

In addition to the General Institute Requirements, the requirements consist of Differential Equations, plus eight additional 12-unit subjects in Course 18 of essentially different content, including at least six advanced subjects (first decimal digit one or higher) that are distributed over at least three distinct areas (at least three distinct first decimal digits). One of these eight subjects must be Linear Algebra. This leaves available 84 units of unrestricted electives. The requirements are flexible in order to accommodate students who pursue programs that combine mathematics with a related field (such as physics, economics, or management) as well as students who are interested in both pure and applied mathematics. More details can be found on the degree chart (*https://catalog.mit.edu/degree-charts/mathematics-course-18/#generalmathematicstext*).

Applied Mathematics Option

Applied mathematics focuses on the mathematical concepts and techniques applied in science, engineering, and computer science. Particular attention is given to the following principles and their mathematical formulations: propagation, equilibrium, stability, optimization, computation, statistics, and random processes.

Sophomores interested in applied mathematics typically enroll in 18.200 Principles of Discrete Applied Mathematics and 18.300 Principles of Continuum Applied Mathematics. Subject 18.200 is devoted to the discrete aspects of applied mathematics and may be taken concurrently with 18.03 Differential Equations. Subject 18.300, offered in the spring term, is devoted to continuous aspects and makes considerable use of differential equations.

The subjects in Group I of the program correspond roughly to those areas of applied mathematics that make heavy use of discrete mathematics, while Group II emphasizes those subjects that deal mainly with continuous processes. Some subjects, such as probability or numerical analysis, have both discrete and continuous aspects.

Students planning to go on to graduate work in applied mathematics should also take some basic subjects in analysis and algebra.

More detail on the Applied Mathematics option can be found on the degree chart (*https://catalog.mit.edu/degree-charts/mathematics-course-18/#appliedmathematicstext*).

Pure Mathematics Option

Pure (or "theoretical") mathematics is the study of the basic concepts and structure of mathematics. Its goal is to arrive at a deeper understanding and an expanded knowledge of mathematics itself.

Traditionally, pure mathematics has been classified into three general fields: analysis, which deals with continuous aspects of mathematics; algebra, which deals with discrete aspects; and geometry. The undergraduate program is designed so that students become familiar with each of these areas. Students also may wish to explore other topics such as logic, number theory, complex analysis, and subjects within applied mathematics.

The subjects 18.701 Algebra I and 18.901 Introduction to Topology are more advanced and should not be elected until a student has had experience with proofs, as in Real Analysis (18.100A, 18.100B, 18.100P or 18.100Q) or 18.700 Linear Algebra.

For more details, see the degree chart (*https://catalog.mit.edu/degree-charts/mathematics-course-18/#theoreticalmathematicstext*).

Bachelor of Science in Mathematics with Computer Science (Course 18-C)

Mathematics and computer science are closely related fields. Problems in computer science are often formalized and solved with mathematical methods. It is likely that many important problems currently facing computer scientists will be solved by researchers skilled in algebra, analysis, combinatorics, logic and/or probability theory, as well as computer science.

The purpose of this program is to allow students to study a combination of these mathematical areas and potential areas of application in computer science. Required subjects include linear algebra (18.06, 18.C06[J], or 18.700) because it is so broadly used, and discrete mathematics (18.062[J] or 18.200) to give experience with proofs and the necessary tools for analyzing algorithms. The required subjects covering complexity (18.404 Theory of Computation or 18.400[J] Computability and Complexity Theory) and algorithms (18.410[J] Design and Analysis of Algorithms) provide an introduction to the most theoretical aspects of computer science. We also require exposure to other areas of computer science (6.1020, 6.1800, 6.4100, or 6.3900) where mathematical issues may also arise. More details can be found on the degree chart (*https://catalog.mit.edu/degree-charts/mathematics-computer-science-course-18-c*).

Some flexibility is allowed in this program. In particular, students may substitute the more advanced subject 18.701 Algebra I for 18.06 Linear Algebra, and, if they already have strong theorem-proving skills, may substitute 18.211 Combinatorial Analysis or 18.212 Algebraic Combinatorics for 18.062[J] Mathematics for Computer Science or 18.200 Principles of Discrete Applied Mathematics.

Minor in Mathematics

The requirements for a Minor in Mathematics are as follows: six 12-unit subjects in mathematics, beyond the Institute's Mathematics Requirement, of essentially different content, including at least three advanced subjects (first decimal digit one or higher).

See the Undergraduate Section for a general description of the minor program (*https://catalog.mit.edu/mit/undergraduate-education/academic-programs/minors*).

Inquiries

For further information, see the department's website (*http://math.mit.edu/academics/undergrad*) or contact Math Academic Services, 617-253-2416.

Graduate Study

The Mathematics Department offers programs covering a broad range of topics leading to the Doctor of Philosophy or Doctor of Science degree. Candidates are admitted to either the Pure or Applied Mathematics programs but are free to pursue interests in both groups. Of the roughly 120 doctoral students, about two thirds are in Pure Mathematics, one third in Applied Mathematics.

The programs in Pure and Applied Mathematics offer basic and advanced classes in analysis, algebra, geometry, Lie theory, logic, number theory, probability, statistics, topology, astrophysics, combinatorics, fluid dynamics, numerical analysis, theoretical physics, and the theory of computation. In addition, many mathematically oriented subjects are offered by other departments. Students in Applied Mathematics are especially encouraged to take subjects in engineering and scientific subjects related to their research.

All students pursue research under the supervision of the faculty and are encouraged to take advantage of the many seminars and colloquia at MIT and in the Boston area.

Doctor of Philosophy or Doctor of Science

The requirements for the Doctor or Philosophy or Doctor of Science in Mathematics (*https://catalog.mit.edu/degree-charts/phd-mathematics*) degree include completion of a minimum of 96 units (8 graduate subjects), an oral qualifying exam, experience in classroom teaching, a thesis proposal, and a thesis containing original research in mathematics. Additional detail about these requirements can be found on the department's website (*http://math.mit.edu/academics/grad/timeline*).

All students pursue research under the supervision of the faculty (*https://math.mit.edu/directory/faculty*). With the assistance of their faculty advisor, each student follows an individualized program of study encompassing the student’s area of interest. Faculty advisors may be members of the Mathematics Department or other MIT departments. Students also are encouraged to take advantage of the many seminars and colloquia (*https://math.mit.edu/news/seminars*) at MIT and in the Boston area.

Students typically receive their degree in five years. The first two years are spent in coursework and research, culminating in an oral examination, which must be attempted by the end of their third term and completed by the end of the second year. Following the oral examination and culmination of their research, the student forms a thesis committee. The thesis committee includes the faculty advisor and at least three other faculty members. The student defends their thesis in a public defense. The thesis must meet high professional standards and make a significant original contribution to the student's chosen research area.

Coursework must be completed with grades of A or B, and students are expected to maintain at least a B+ average in each semester. At most, one of the eight subjects should be a reading course. Harvard math graduate subjects may occasionally be used if taken for credit. With prior approval of the Graduate Co-chairs, one relevant advanced undergraduate math subject and relevant graduate subjects from other departments may be used. Note that subjects taken under the graduate P/D/F option cannot be used to fulfill this requirement. Students in Applied Mathematics must satisfy an additional breadth requirement (*https://math.mit.edu/academics/grad/timeline/plan.html*) as part of their plan of study.

Teaching is an important part of the academic profession and provides excellent experience in public presentation skills. All graduate students are required to complete at least one semester of classroom teaching as part of their graduate training and are encouraged to do more.

Interdisciplinary Programs

Computational Science and Engineering

Students with primary interest in computational science may also consider applying to the interdisciplinary Computational Science and Engineering (CSE) program, with which the Mathematics Department is affiliated. For more information, see the CSE website (*http://cse.mit.edu/programs*).

Mathematics and Statistics

The Interdisciplinary Doctoral Program in Statistics provides training in statistics, including classical statistics and probability as well as computation and data analysis, to students who wish to integrate these valuable skills into their primary academic program. The program is administered jointly by the departments of Aeronautics and Astronautics, Economics, Mathematics, Mechanical Engineering, Physics, and Political Science, and the Statistics and Data Science Center within the Institute for Data, Systems, and Society. It is open to current doctoral students in participating departments. For more information, including department-specific requirements, see the full program description (*https://catalog.mit.edu/interdisciplinary/graduate-programs/phd-statistics*) under Interdisciplinary Graduate Programs.

Financial Support

Financial support is guaranteed for up to five years to students making satisfactory academic progress. Financial aid after the first year is usually in the form of a teaching or research assistantship.

Inquiries

For further information, see the department's website (*http://math.mit.edu/academics/grad*) or contact Math Academic Services, 617-253-2416.

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David A. Vogan, PhD
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General Mathematics

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

Differentiation and integration of functions of one variable, with applications. Informal treatment of limits and continuity. Differentiation: definition, rules, application to graphing, rates, approximations, and extremum problems. Indefinite integration; separable first-order differential equations. Definite integral; fundamental theorem of calculus. Applications of integration to geometry and science. Elementary functions. Techniques of integration. Polar coordinates. L'Hopital's rule. Improper integrals. Infinite series: geometric, p-harmonic, simple comparison tests, power series for some elementary functions.
Fall: L. Guth. Spring: Information: W. Minicozzi

18.01A Calculus
Prereq: Knowledge of differentiation and elementary integration
U (Fall; first half of term)
5-0-7 units. CALC I
Credit cannot also be received for 18.01, CC.1801, ES.1801, ES.181A

Six-week review of one-variable calculus, emphasizing material not on the high-school AB syllabus: integration techniques and applications, improper integrals, infinite series, applications to other topics, such as probability and statistics, as time permits. Prerequisites: one year of high-school calculus or the equivalent, with a score of 5 on the AB Calculus test (or the AB portion of the BC test, or an equivalent score on a standard international exam), or equivalent college transfer credit, or a passing grade on the first half of the 18.01 advanced standing exam.
A. Moitra

18.02 Calculus
Prereq: Calculus I (GIR)
U (Fall, Spring)
5-0-7 units. CALC II
Credit cannot also be received for 18.022, 18.02A, CC.1802, ES.1802, ES.182A

Calculus of several variables. Vector algebra in 3-space, determinants, matrices. Vector-valued functions of one variable, space motion. Scalar functions of several variables: partial differentiation, gradient, optimization techniques. Double integrals and line integrals in the plane; exact differentials and conservative fields; Green's theorem and applications, triple integrals, line and surface integrals in space, Divergence theorem, Stokes' theorem; applications.
Fall: S Dyatlov. Spring: D Jerison

18.02A Calculus
Prereq: Calculus I (GIR)
U (Fall, IAP, Spring; second half of term)
5-0-7 units. CALC II
Credit cannot also be received for 18.02, 18.022, CC.1802, ES.1802, ES.182A

First half is taught during the last six weeks of the Fall term; covers material in the first half of 18.02 (through double integrals). Second half of 18.02A can be taken either during IAP (daily lectures) or during the second half of the Spring term; it covers the remaining material in 18.02.
Fall, IAP: J. W. M. Bush. Spring: D. Jerison

18.022 Calculus
Prereq: Calculus I (GIR)
U (Fall)
5-0-7 units. CALC II
Credit cannot also be received for 18.02, 18.02A, CC.1802, 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. Parametrized 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.
W. Minicozzi

18.03 Differential Equations
Prereq: None. *Coreq: Calculus II (GIR)*
U (Fall, Spring)
5-0-7 units. REST
Credit cannot also be received for CC.1803, 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, 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: L. Demanet

18.031 System Functions and the Laplace Transform
Prereq: None. *Coreq: 18.03*
U (IAP)
1-0-2 units

Studies basic continuous control theory as well as representation of functions in the complex frequency domain. Covers generalized functions, unit impulse response, and convolution; and Laplace transform, system (or transfer) function, and the pole diagram. Includes examples from mechanical and electrical engineering.
Information: H. R. Miller

18.032 Differential Equations
Prereq: None. *Coreq: Calculus II (GIR)*
U (Spring)
5-0-7 units. REST

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.
A. Lawrie

18.04 Complex Variables with Applications
Prereq: Calculus II (GIR) and (18.03 or 18.032)
U (Fall)
4-0-8 units
Credit cannot also be received for 18.075, 18.0751

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 II (GIR)
U (Spring)
4-0-8 units. REST

Elementary introduction with applications. Basic probability models. Combinatorics. Random variables. Discrete and continuous probability distributions. Statistical estimation and testing. Confidence intervals. Introduction to linear regression.
J. French

18.06 Linear Algebra
Prereq: Calculus II (GIR)
U (Fall, Spring)
4-0-8 units. REST
Credit cannot also be received for 6.C06[J], 18.700, 18.C06[J], ES.1806

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 linear algebra software. Compared with 18.700, more emphasis on matrix algorithms and many applications.
Fall: TBD. Spring: A. Borodin

18.C06[J] Linear Algebra and Optimization
Same subject as 6.C06[J]
Prereq: Calculus II (GIR)
U (Fall)
5-0-7 units. REST
Credit cannot also be received for 18.06, 18.700, ES.1806

Introductory course in linear algebra and optimization, assuming no prior exposure to linear algebra and starting from the basics, including vectors, matrices, eigenvalues, singular values, and least squares. Covers the basics in optimization including convex optimization, linear/quadratic programming, gradient descent, and regularization, building on insights from linear algebra. Explores a variety of applications in science and engineering, where the tools developed give powerful ways to understand complex systems and also extract structure from data.
A. Moitra, P. Parrilo

18.062[J] Mathematics for Computer Science
Same subject as 6.1200[J]
Prereq: Calculus I (GIR)
U (Fall, Spring)
5-0-7 units. REST

See description under subject 6.1200[J].
Z. R. Abel, F. T. Leighton, A. Moitra

18.063 Matrix Calculus for Machine Learning and Beyond (New)
Prereq: Calculus II (GIR) and 18.06
U (IAP; partial term)
1-0-2 units

Covers a coherent approach to matrix calculus, showing techniques that allow the student to think of a matrix holistically, rather than as an array of scalars; generalize and compute derivatives of important matrix factorizations and other complicated-looking operations; and understand how differentiation formulas must be reimagined in large-scale computing. Discusses "adjoint" or "reverse-mode" differentiation, custom vector-Jacobian products, and how modern automatic differentiation is more computer science than calculus.
S. Johnson, A. Edelman

18.065 Matrix Methods in Data Analysis, Signal Processing, and Machine Learning
Subject meets with 18.0651
Prereq: 18.06
U (Spring)
3-0-9 units

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.
Staff

18.0651 Matrix Methods in Data Analysis, Signal Processing, and Machine Learning
Subject meets with 18.065
Prereq: 18.06
G (Spring)
3-0-9 units

Reviews linear algebra with applications to life sciences, finance, engineering, and big data. Covers singular value decomposition, weighted least squares, signal and image processing, principal component analysis, covariance and correlation matrices, directed and undirected graphs, matrix factorizations, neural nets, machine learning, and computations with large matrices. Students in Course 18 must register for the undergraduate version, 18.065.
Staff

18.075 Methods for Scientists and Engineers
Subject meets with 18.0751
Prereq: Calculus II (GIR) and 18.03
U (Spring)
3-0-9 units
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

18.0751 Methods for Scientists and Engineers
Subject meets with 18.075
Prereq: Calculus II (GIR) and 18.03
G (Spring)
3-0-9 units
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. Students in Courses 6, 8, 12, 18, and 22 must register for undergraduate version, 18.075.
H. Cheng

18.085 Computational Science and Engineering I
Subject meets with 18.0851
Prereq: Calculus II (GIR) and (18.03 or 18.032)
U (Fall, Spring, Summer)
3-0-9 units

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: D. Kouskoulas. Spring: Staff

18.0851 Computational Science and Engineering I
Subject meets with 18.085
Prereq: Calculus II (GIR) and (18.03 or 18.032)
G (Fall, Spring, Summer)
3-0-9 units

Review of linear algebra, applications to networks, structures, and estimation, finite difference and finite element solution of differential equations, Laplace's equation and potential flow, boundary-value problems, Fourier series, discrete Fourier transform, convolution. Frequent use of MATLAB in a wide range of scientific and engineering applications. Students in Course 18 must register for the undergraduate version, 18.085.
Fall: D. Kouskoulas. Spring: Staff

18.086 Computational Science and Engineering II
Subject meets with 18.0861
Prereq: Calculus II (GIR) and (18.03 or 18.032)
U (Spring)
Not offered regularly; consult department
3-0-9 units

Initial value problems: finite difference methods, accuracy and stability, heat equation, wave equations, conservation laws and shocks, level sets, Navier-Stokes. Solving large systems: elimination with reordering, iterative methods, preconditioning, multigrid, Krylov subspaces, conjugate gradients. Optimization and minimum principles: weighted least squares, constraints, inverse problems, calculus of variations, saddle point problems, linear programming, duality, adjoint methods.
Information: W. G. Strang

18.0861 Computational Science and Engineering II
Subject meets with 18.086
Prereq: Calculus II (GIR) and (18.03 or 18.032)
G (Spring)
Not offered regularly; consult department
3-0-9 units

Initial value problems: finite difference methods, accuracy and stability, heat equation, wave equations, conservation laws and shocks, level sets, Navier-Stokes. Solving large systems: elimination with reordering, iterative methods, preconditioning, multigrid, Krylov subspaces, conjugate gradients. Optimization and minimum principles: weighted least squares, constraints, inverse problems, calculus of variations, saddle point problems, linear programming, duality, adjoint methods. Students in Course 18 must register for the undergraduate version, 18.086.
Information: W. G. Strang

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

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: W. Minicozzi

18.090 Introduction to Mathematical Reasoning
Prereq: None. *Coreq: Calculus II (GIR)*
U (Spring)
3-0-9 units. REST

Focuses on understanding and constructing mathematical arguments. Discusses foundational topics (such as infinite sets, quantifiers, and methods of proof) as well as selected concepts from algebra (permutations, vector spaces, fields) and analysis (sequences of real numbers). Particularly suitable for students desiring additional experience with proofs before going on to more advanced mathematics subjects or subjects in related areas with significant mathematical content.
S. Dyatlov, B. Poonen, P. Seidel

18.091 Introduction to Metric Spaces (New)
Prereq: 18.100A
U (IAP; partial term)
1-0-2 units

Covers metrics, open and closed sets, continuous functions (from a topological perspective), function spaces, completeness, and compactness. Aims to provide more complex concepts and proofs for students who have taken 18.100A as their real analysis subject.
W. Minicozzi

18.094[J] Teaching College-Level Science and Engineering
Same subject as 1.95[J], 5.95[J], 7.59[J], 8.395[J]
Subject meets with 2.978
Prereq: None
G (Fall)
2-0-2 units

See description under subject 5.95[J].
J. Rankin

18.095 Mathematics Lecture Series
Prereq: Calculus I (GIR)
U (IAP)
2-0-4 units
Can be repeated for credit.

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: W. Minicozzi

18.098 Internship in Mathematics
Prereq: Permission of instructor
U (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Provides academic credit for students pursuing internships to gain practical experience in the applications of mathematical concepts and methods.
Information: W. Minicozzi

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. May not be used to satisfy Mathematics major requirements.
Information: W. Minicozzi

Analysis

18.1001 Real Analysis
Subject meets with 18.100A
Prereq: Calculus II (GIR)
G (Fall, Spring)
3-0-9 units
Credit cannot also be received for 18.1002, 18.100A, 18.100B, 18.100P, 18.100Q

Covers fundamentals of mathematical analysis: convergence of sequences and series, continuity, differentiability, Riemann integral, sequences and series of functions, uniformity, interchange of limit operations. Shows the utility of abstract concepts and teaches understanding and construction of proofs. Proofs and definitions are less abstract than in 18.100B. Gives applications where possible. Concerned primarily with the real line. Students in Course 18 must register for undergraduate version 18.100A.
Fall: Q. Deng. Spring: J. Zhu

18.1002 Real Analysis
Subject meets with 18.100B
Prereq: Calculus II (GIR)
G (Fall, Spring)
3-0-9 units
Credit cannot also be received for 18.1001, 18.100A, 18.100B, 18.100P, 18.100Q

Covers fundamentals of mathematical analysis: convergence of sequences and series, continuity, differentiability, Riemann integral, sequences and series of functions, uniformity, interchange of limit operations. Shows the utility of abstract concepts and teaches understanding and construction of proofs. More demanding than 18.100A, for students with more mathematical maturity. Places more emphasis on point-set topology and n-space. Students in Course 18 must register for undergraduate version 18.100B.
Fall: R. Melrose. Spring: G. Franz

18.100A Real Analysis
Subject meets with 18.1001
Prereq: Calculus II (GIR)
U (Fall, Spring)
3-0-9 units
Credit cannot also be received for 18.1001, 18.1002, 18.100B, 18.100P, 18.100Q

Covers fundamentals of mathematical analysis: convergence of sequences and series, continuity, differentiability, Riemann integral, sequences and series of functions, uniformity, interchange of limit operations. Shows the utility of abstract concepts and teaches understanding and construction of proofs. Proofs and definitions are less abstract than in 18.100B. Gives applications where possible. Concerned primarily with the real line.
Fall: Q. Deng. Spring: J. Zhu

18.100B Real Analysis
Subject meets with 18.1002
Prereq: Calculus II (GIR)
U (Fall, Spring)
3-0-9 units
Credit cannot also be received for 18.1001, 18.1002, 18.100A, 18.100P, 18.100Q

Covers fundamentals of mathematical analysis: convergence of sequences and series, continuity, differentiability, Riemann integral, sequences and series of functions, uniformity, interchange of limit operations. Shows the utility of abstract concepts and teaches understanding and construction of proofs. More demanding than 18.100A, for students with more mathematical maturity. Places more emphasis on point-set topology and n-space.
Fall: R. Melrose. Spring: G. Franz

18.100P Real Analysis
Prereq: Calculus II (GIR)
U (Spring)
4-0-11 units
Credit cannot also be received for 18.1001, 18.1002, 18.100A, 18.100B, 18.100Q

Covers fundamentals of mathematical analysis: convergence of sequences and series, continuity, differentiability, Riemann integral, sequences and series of functions, uniformity, interchange of limit operations. Shows the utility of abstract concepts and teaches understanding and construction of proofs. Proofs and definitions are less abstract than in 18.100B. Gives applications where possible. Concerned primarily with the real line. Includes instruction and practice in written communication. Enrollment limited.
K. Naff

18.100Q Real Analysis
Prereq: Calculus II (GIR)
U (Fall)
4-0-11 units
Credit cannot also be received for 18.1001, 18.1002, 18.100A, 18.100B, 18.100P

Covers fundamentals of mathematical analysis: convergence of sequences and series, continuity, differentiability, Riemann integral, sequences and series of functions, uniformity, interchange of limit operations. Shows the utility of abstract concepts and teaches understanding and construction of proofs. More demanding than 18.100A, for students with more mathematical maturity. Places more emphasis on point-set topology and n-space. Includes instruction and practice in written communication. Enrollment limited.
C. Oh

18.101 Analysis and Manifolds
Subject meets with 18.1011
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
U (Fall)
3-0-9 units

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.
M. Jezequel

18.1011 Analysis and Manifolds
Subject meets with 18.101
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
G (Fall)
3-0-9 units

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. 18.9011 helpful but not required. Students in Course 18 must register for the undergraduate version, 18.101.
M. Jezequel

18.102 Introduction to Functional Analysis
Subject meets with 18.1021
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
U (Spring)
3-0-9 units

Normed spaces, completeness, functionals, Hahn-Banach theorem, duality, operators. Lebesgue measure, measurable functions, integrability, completeness of L-p spaces. Hilbert space. Compact, Hilbert-Schmidt and trace class operators. Spectral theorem.
M. Jezequel

18.1021 Introduction to Functional Analysis
Subject meets with 18.102
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
G (Spring)
3-0-9 units

Normed spaces, completeness, functionals, Hahn-Banach theorem, duality, operators. Lebesgue measure, measurable functions, integrability, completeness of L-p spaces. Hilbert space. Compact, Hilbert-Schmidt and trace class operators. Spectral theorem. Students in Course 18 must register for the undergraduate version, 18.102.
M. Jezequel

18.103 Fourier Analysis: Theory and Applications
Subject meets with 18.1031
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-0-9 units

Roughly half the subject devoted to the theory of the Lebesgue integral with applications to probability, and half to Fourier series and Fourier integrals.
J. Shi

18.1031 Fourier Analysis: Theory and Applications
Subject meets with 18.103
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
G (Spring)
3-0-9 units

Roughly half the subject devoted to the theory of the Lebesgue integral with applications to probability, and half to Fourier series and Fourier integrals. Students in Course 18 must register for the undergraduate version, 18.103.
J. Shi

18.104 Seminar in Analysis
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q
U (Fall, Spring)
3-0-9 units

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.
Fall: T. Ozuch-Meersseman. Spring: G. Staffilani

18.112 Functions of a Complex Variable
Subject meets with 18.1121
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
U (Fall)
3-0-9 units

Studies the basic properties of analytic functions of one complex variable. Conformal mappings and the Poincare model of non-Euclidean geometry. Cauchy-Goursat theorem and Cauchy integral formula. Taylor and Laurent decompositions. Singularities, residues and computation of integrals. Harmonic functions and Dirichlet's problem for the Laplace equation. The partial fractions decomposition. Infinite series and infinite product expansions. The Gamma function. The Riemann mapping theorem. Elliptic functions.
A. Lawrie

18.1121 Functions of a Complex Variable
Subject meets with 18.112
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
G (Fall)
3-0-9 units

Studies the basic properties of analytic functions of one complex variable. Conformal mappings and the Poincare model of non-Euclidean geometry. Cauchy-Goursat theorem and Cauchy integral formula. Taylor and Laurent decompositions. Singularities, residues and computation of integrals. Harmonic functions and Dirichlet's problem for the Laplace equation. The partial fractions decomposition. Infinite series and infinite product expansions. The Gamma function. The Riemann mapping theorem. Elliptic functions. Students in Course 18 must register for the undergraduate version, 18.112.
A. Lawrie

18.116 Riemann Surfaces
Prereq: 18.112
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Riemann surfaces, uniformization, Riemann-Roch Theorem. Theory of elliptic functions and modular forms. Some applications, such as to number theory.
P. I. Etingof

18.117 Topics in Several Complex Variables
Prereq: 18.112 and 18.965
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units
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.
B. Poonen

18.118 Topics in Analysis
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units
Can be repeated for credit.

Topics vary from year to year.
S. Dyatlov

18.125 Measure Theory and Analysis
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Provides a rigorous introduction to Lebesgue's theory of measure and integration. Covers material that is essential in analysis, probability theory, and differential geometry.
M. Jezequel

18.137 Topics in Geometric Partial Differential Equations
Prereq: Permission of instructor
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units
Can be repeated for credit.

Topics vary from year to year.
T. Colding

18.152 Introduction to Partial Differential Equations
Subject meets with 18.1521
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
U (Fall)
3-0-9 units

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.
T. Collins

18.1521 Introduction to Partial Differential Equations
Subject meets with 18.152
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
G (Spring)
3-0-9 units

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. Students in Course 18 must register for the undergraduate version, 18.152.
T. Collins

18.155 Differential Analysis I
Prereq: 18.102 or 18.103
G (Fall)
3-0-9 units

First part of a two-subject sequence. Review of Lebesgue integration. Lp spaces. Distributions. Fourier transform. Sobolev spaces. Spectral theorem, discrete and continuous spectrum. Homogeneous distributions. Fundamental solutions for elliptic, hyperbolic and parabolic differential operators. Recommended prerequisite: 18.112.
S. Dyatlov

18.156 Differential Analysis II
Prereq: 18.155
G (Spring)
3-0-9 units

Second part of a two-subject sequence. Covers variable coefficient elliptic, parabolic and hyperbolic partial differential equations.
D. Jerison

18.157 Introduction to Microlocal Analysis
Prereq: 18.155
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

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 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units
Can be repeated for credit.

Topics vary from year to year.
L. Guth

18.199 Graduate Analysis Seminar
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units
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

Discrete Applied Mathematics

18.200 Principles of Discrete Applied Mathematics
Prereq: None. *Coreq: 18.06*
U (Spring)
4-0-11 units
Credit cannot also be received for 18.200A

Study of illustrative topics in discrete applied mathematics, including probability theory, information theory, coding theory, secret codes, generating functions, and linear programming. Instruction and practice in written communication provided. Enrollment limited.
P. W. Shor, A. Moitra

18.200A Principles of Discrete Applied Mathematics
Prereq: None. *Coreq: 18.06*
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units
Credit cannot also be received for 18.200

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

18.204 Undergraduate Seminar in Discrete Mathematics
Prereq: ((6.1200[J] or 18.200) and (18.06, 18.700, or 18.701)) or permission of instructor
U (Fall, Spring)
3-0-9 units

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.
J. He, D. Mikulincer, M. Sherman-Bennett, A. Weigandt

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

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.
A. Weigandt

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

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

18.217 Combinatorial Theory
Prereq: Permission of instructor
G (Fall)
3-0-9 units
Can be repeated for credit.

Content varies from year to year.
A. Postnikov

18.218 Topics in Combinatorics
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units
Can be repeated for credit.

Topics vary from year to year.
L. Sauermann

18.219 Seminar in Combinatorics
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.

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

18.225 Graph Theory and Additive Combinatorics
Prereq: ((18.701 or 18.703) and (18.100A, 18.100B, 18.100P, or 18.100Q)) or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

Introduction to extremal graph theory and additive combinatorics. Highlights common themes, such as the dichotomy between structure versus pseudorandomness. Topics include Turan-type problems, Szemeredi's regularity lemma and applications, pseudorandom graphs, spectral graph theory, graph limits, arithmetic progressions (Roth, Szemeredi, Green-Tao), discrete Fourier analysis, Freiman's theorem on sumsets and structure. Discusses current research topics and open problems.
Y. Zhao

18.226 Probabilistic Methods in Combinatorics
Prereq: (18.211, 18.600, and (18.100A, 18.100B, 18.100P, or 18.100Q)) or permission of instructor
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units

Introduction to the probabilistic method, a fundamental and powerful technique in combinatorics and theoretical computer science. Focuses on methodology as well as combinatorial applications. Suitable for students with strong interest and background in mathematical problem solving. Topics include linearity of expectations, alteration, second moment, Lovasz local lemma, correlation inequalities, Janson inequalities, concentration inequalities, entropy method.
Y. Zhao

Continuous Applied Mathematics

18.300 Principles of Continuum Applied Mathematics
Prereq: Calculus II (GIR) and (18.03 or 18.032)
U (Spring)
3-0-9 units

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.
B. Geshkovski

18.303 Linear Partial Differential Equations: Analysis and Numerics
Prereq: 18.06 or 18.700
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

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. Some programming required for homework and final project.
V. Heinonen

18.305 Advanced Analytic Methods in Science and Engineering
Prereq: 18.04, 18.075, or 18.112
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

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 18.032) and (18.04, 18.075, or 18.112)
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Concepts and techniques for partial differential equations, especially nonlinear. Diffusion, dispersion and other phenomena. Initial and boundary value problems. Normal mode analysis, Green's functions, and transforms. Conservation laws, kinematic waves, hyperbolic equations, characteristics shocks, simple waves. Geometrical optics, caustics. Free-boundary problems. Dimensional analysis. Singular perturbation, boundary layers, homogenization. Variational methods. Solitons. Applications from fluid dynamics, materials science, optics, traffic flow, etc.
R. R. Rosales

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

Topics vary from year to year.
L. Demanet

18.330 Introduction to Numerical Analysis
Prereq: Calculus II (GIR) and (18.03 or 18.032)
U (Spring)
3-0-9 units

Basic techniques for the efficient numerical solution of problems in science and engineering. Root finding, interpolation, approximation of functions, integration, differential equations, direct and iterative methods in linear algebra. Knowledge of programming in a language such as MATLAB, Python, or Julia is helpful.
L. Demanet

18.335[J] Introduction to Numerical Methods
Same subject as 6.7310[J]
Prereq: 18.06, 18.700, or 18.701
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Advanced introduction to numerical analysis: accuracy and efficiency of numerical algorithms. In-depth coverage of sparse-matrix/iterative and dense-matrix algorithms in numerical linear algebra (for linear systems and eigenproblems). Floating-point arithmetic, backwards error analysis, conditioning, and stability. Other computational topics (e.g., numerical integration or nonlinear optimization) may also be surveyed. Final project involves some programming.
A. J. Horning

18.336[J] Fast Methods for Partial Differential and Integral Equations
Same subject as 6.7340[J]
Prereq: 6.7300[J], 16.920[J], 18.085, 18.335[J], or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall, Spring)
3-0-9 units

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.
K. Burns

18.337[J] Parallel Computing and Scientific Machine Learning
Same subject as 6.7320[J]
Prereq: 18.06, 18.700, or 18.701
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Introduction to scientific machine learning with an emphasis on developing scalable differentiable programs. Covers scientific computing topics (numerical differential equations, dense and sparse linear algebra, Fourier transformations, parallelization of large-scale scientific simulation) simultaneously with modern data science (machine learning, deep neural networks, automatic differentiation), focusing on the emerging techniques at the connection between these areas, such as neural differential equations and physics-informed deep learning. Provides direct experience with the modern realities of optimizing code performance for supercomputers, GPUs, and multicores in a high-level language.
A. Edelman

18.338 Eigenvalues of Random Matrices
Prereq: 18.701 or permission of instructor
G (Fall)
3-0-9 units

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 Julia helpful, but not required.
A. Edelman

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

See description under subject 12.009[J].
D. H. Rothman

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

See description under subject 12.006[J].
D. Rothman

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

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.
B. Primkulov

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

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. Students in Courses 1, 12, and 18 must register for undergraduate version, 18.354[J].
B. Primkulov

18.355 Fluid Mechanics
Prereq: 2.25, 12.800, or 18.354[J]
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

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: 2.25, 12.800, 18.354[J], 18.355, or permission of instructor
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

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

18.358[J] Nonlinear Dynamics and Turbulence
Same subject as 1.686[J], 2.033[J]
Subject meets with 1.068
Prereq: 1.060A
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-2-7 units

See description under subject 1.686[J].
L. Bourouiba

18.367 Waves and Imaging
Prereq: Permission of instructor
Acad Year 2024-2025: G (Fall)
Acad Year 2025-2026: Not offered
3-0-9 units

The mathematics of inverse problems involving waves, with examples taken from reflection seismology, synthetic aperture radar, and computerized tomography. Suitable for graduate students from all departments who have affinities with applied mathematics. Topics include acoustic, elastic, electromagnetic wave equations; geometrical optics; scattering series and inversion; migration and backprojection; adjoint-state methods; Radon and curvilinear Radon transforms; microlocal analysis of imaging; optimization, regularization, and sparse regression.
L. Demanet

18.369[J] Mathematical Methods in Nanophotonics
Same subject as 8.315[J]
Prereq: 8.07, 18.303, or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

High-level approaches to understanding complex optical media, structured on the scale of the wavelength, that are not generally analytically soluable. 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.
S. G. Johnson

18.376[J] Wave Propagation
Same subject as 1.138[J], 2.062[J]
Prereq: 2.003[J] and 18.075
G (Spring)
Not offered regularly; consult department
3-0-9 units

See description under subject 2.062[J].
T. R. Akylas, R. R. Rosales

18.377[J] Nonlinear Dynamics and Waves
Same subject as 1.685[J], 2.034[J]
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

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.
R. R. Rosales

18.384 Undergraduate Seminar in Physical Mathematics
Prereq: 12.006[J], 18.300, 18.354[J], or permission of instructor
U (Fall)
3-0-9 units

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.
O. Kodio

18.385[J] Nonlinear Dynamics and Chaos
Same subject as 2.036[J]
Prereq: 18.03 or 18.032
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Introduction to the theory of nonlinear dynamical systems with applications from science and engineering. Local and global existence of solutions, dependence on initial data and parameters. Elementary bifurcations, normal forms. Phase plane, limit cycles, relaxation oscillations, Poincare-Bendixson theory. Floquet theory. Poincare maps. Averaging. Near-equilibrium dynamics. Synchronization. Introduction to chaos. Universality. Strange attractors. Lorenz and Rossler systems. Hamiltonian dynamics and KAM theory. Uses MATLAB computing environment.
R. R. Rosales

18.397 Mathematical Methods in Physics
Prereq: 18.745 or some familiarity with Lie theory
G (Fall)
Not offered regularly; consult department
3-0-9 units
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

Theoretical Computer Science

18.400[J] Computability and Complexity Theory
Same subject as 6.1400[J]
Prereq: (6.1200[J] and 6.1210) or permission of instructor
U (Spring)
4-0-8 units

See description under subject 6.1400[J].
R. Williams, R. Rubinfeld

18.404 Theory of Computation
Subject meets with 6.5400[J], 18.4041[J]
Prereq: 6.1200[J] or 18.200
U (Fall)
4-0-8 units

A more extensive and theoretical treatment of the material in 6.1400[J]/18.400[J], 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

18.4041[J] Theory of Computation
Same subject as 6.5400[J]
Subject meets with 18.404
Prereq: 6.1200[J] or 18.200
G (Fall)
4-0-8 units

A more extensive and theoretical treatment of the material in 6.1400[J]/18.400[J], 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. Students in Course 18 must register for the undergraduate version, 18.404.
M. Sipser

18.405[J] Advanced Complexity Theory
Same subject as 6.5410[J]
Prereq: 18.404
G (Spring)
3-0-9 units

Current research topics in computational complexity theory. Nondeterministic, alternating, probabilistic, and parallel computation models. Boolean circuits. Complexity classes and complete sets. The polynomial-time hierarchy. Interactive proof systems. Relativization. Definitions of randomness. Pseudo-randomness and derandomizations. Interactive proof systems and probabilistically checkable proofs.
R. Williams

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

Study of areas of current interest in theoretical computer science. Topics vary from term to term.
Fall: D. Minzer. Spring: A. Moitra

18.410[J] Design and Analysis of Algorithms
Same subject as 6.1220[J]
Prereq: 6.1200[J] and 6.1210
U (Fall, Spring)
4-0-8 units

See description under subject 6.1220[J].
E. Demaine, M. Goemans, S. Raghuraman

18.413 Introduction to Computational Molecular Biology
Subject meets with 18.417
Prereq: 6.1210 or permission of instructor
U (Spring)
Not offered regularly; consult department
3-0-9 units

Introduction to computational molecular biology with a focus on the basic computational algorithms used to solve problems in practice. Covers classical techniques in the field for solving problems such as genome sequencing, assembly, and search; detecting genome rearrangements; constructing evolutionary trees; analyzing mass spectrometry data; connecting gene expression to cellular function; and machine learning for drug discovery. Prior knowledge of biology is not required. Particular emphasis on problem solving, collaborative learning, theoretical analysis, and practical implementation of algorithms. Students taking graduate version complete additional and more complex assignments.
B. Berger

18.415[J] Advanced Algorithms
Same subject as 6.5210[J]
Prereq: 6.1220[J] and (6.1200[J], 6.3700, or 18.600)
G (Fall)
5-0-7 units

See description under subject 6.5210[J].
A. Moitra, D. R. Karger

18.416[J] Randomized Algorithms
Same subject as 6.5220[J]
Prereq: (6.1200[J] or 6.3700) and (6.1220[J] or 6.5210[J])
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
5-0-7 units

See description under subject 6.5220[J].
D. R. Karger

18.417 Introduction to Computational Molecular Biology
Subject meets with 18.413
Prereq: 6.1210 or permission of instructor
G (Spring)
3-0-9 units

Introduction to computational molecular biology with a focus on the basic computational algorithms used to solve problems in practice. Covers classical techniques in the field for solving problems such as genome sequencing, assembly, and search; detecting genome rearrangements; constructing evolutionary trees; analyzing mass spectrometry data; connecting gene expression to cellular function; and machine learning for drug discovery. Prior knowledge of biology is not required. Particular emphasis on problem solving, collaborative learning, theoretical analysis, and practical implementation of algorithms. Students taking graduate version complete additional and more complex assignments.
B. Berger

18.418[J] Topics in Computational Molecular Biology
Same subject as HST.504[J]
Prereq: 6.8701, 18.417, or permission of instructor
G (Fall)
3-0-9 units
Can be repeated for credit.

Covers current research topics in computational molecular biology. Recent research papers presented from leading conferences such as the International Conference on Computational Molecular Biology (RECOMB) and the Conference on Intelligent Systems for Molecular Biology (ISMB). Topics include original research (both theoretical and experimental) in comparative genomics, sequence and structure analysis, molecular evolution, proteomics, gene expression, transcriptional regulation, biological networks, drug discovery, and privacy. Recent research by course participants also covered. Participants will be expected to present individual projects to the class.
B. Berger

18.424 Seminar in Information Theory
Prereq: (6.3700, 18.05, or 18.600) and (18.06, 18.700, or 18.701)
U (Fall)
3-0-9 units

Considers various topics in information theory, including data compression, Shannon's Theorems, and error-correcting codes. Students present and discuss the subject matter. Instruction and practice in written and oral communication provided. Enrollment limited.
J. Kelner

18.425[J] Foundations of Cryptography
Same subject as 6.5620[J]
Prereq: 6.1220[J], 6.1400[J], or 18.4041[J]
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

See description under subject 6.5620[J].
S. Goldwasser, S. Micali, V. Vaikuntanathan

18.434 Seminar in Theoretical Computer Science
Prereq: 6.1220[J]
U (Fall)
3-0-9 units

Topics vary from year to year. Students present and discuss the subject matter. Instruction and practice in written and oral communication provided. Enrollment limited.
Fall: E. Mossel. Spring: D. Minzer

18.435[J] Quantum Computation
Same subject as 2.111[J], 6.6410[J], 8.370[J]
Prereq: 8.05, 18.06, 18.700, 18.701, or 18.C06[J]
G (Fall)
3-0-9 units

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, A. Harrow, P. Shor

18.436[J] Quantum Information Science
Same subject as 6.6420[J], 8.371[J]
Prereq: 18.435[J]
G (Spring)
3-0-9 units

See description under subject 8.371[J].
I. Chuang, A. Harrow

18.437[J] Distributed Algorithms
Same subject as 6.5250[J]
Prereq: 6.1220[J]
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

See description under subject 6.5250[J].
M. Ghaffari, N. A. Lynch

18.453 Combinatorial Optimization
Subject meets with 18.4531
Prereq: 18.06, 18.700, or 18.701
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-0-9 units

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 18.200) helpful.
Information: M. X. Goemans

18.4531 Combinatorial Optimization
Subject meets with 18.453
Prereq: 18.06, 18.700, or 18.701
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

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 18.200) helpful. Students in Course 18 must register for the undergraduate version, 18.453.
Information: M. X. Goemans

18.455 Advanced Combinatorial Optimization
Prereq: 18.453 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

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

18.456[J] Algebraic Techniques and Semidefinite Optimization
Same subject as 6.7230[J]
Prereq: 6.7210[J] or 15.093
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

See description under subject 6.7230[J].
P. Parrilo

Logic

18.504 Seminar in Logic
Prereq: (18.06, 18.510, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

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 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

Propositional and predicate logic. Zermelo-Fraenkel set theory. Ordinals and cardinals. Axiom of choice and transfinite induction. Elementary model theory: completeness, compactness, and Lowenheim-Skolem theorems. Godel's incompleteness theorem.
H. Cohn

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

More rigorous treatment of basic mathematical logic, Godel's theorems, and Zermelo-Fraenkel set theory. First-order logic. Models and satisfaction. Deduction and proof. Soundness and completeness. Compactness and its consequences. Quantifier elimination. Recursive sets and functions. Incompleteness and undecidability. Ordinals and cardinals. Set-theoretic formalization of mathematics.
Information: B. Poonen

Probability and Statistics

18.600 Probability and Random Variables
Prereq: Calculus II (GIR)
U (Fall, Spring)
4-0-8 units. REST
Credit cannot also be received for 6.3700, 6.3702

Probability spaces, random variables, distribution functions. Binomial, geometric, hypergeometric, Poisson distributions. Uniform, exponential, normal, gamma and beta distributions. Conditional probability, Bayes theorem, joint distributions. Chebyshev inequality, law of large numbers, and central limit theorem. Credit cannot also be received for 6.041A or 6.041B.
Fall: S. Sheffield. Spring: J. Kelner

18.604 Seminar In Probability Theory (New)
Prereq: 18.05 or 18.600
U (Spring)
3-0-9 units

Students work on group presentations on topics selected by students from a provided list of suggestions. Topics may include Benford's law, random walks and electrical networks, and Brownian motions. Assignments include three group presentations, two individual presentations, and a final individual term paper. Instruction in oral and written communication provided to effectively communicate about probability theory. Limited to 16.
H. Cohn, S. Sheffield

18.615 Introduction to Stochastic Processes
Prereq: 6.3700 or 18.600
G (Spring)
3-0-9 units

Basics of stochastic processes. Markov chains, Poisson processes, random walks, birth and death processes, Brownian motion.
J. He

18.619[J] Discrete Probability and Stochastic Processes
Same subject as 6.7720[J], 15.070[J]
Prereq: 6.3702, 6.7700[J], 18.100A, 18.100B, or 18.100Q
G (Spring)
3-0-9 units

See description under subject 15.070[J].
G. Bresler, D. Gamarnik, E. Mossel, Y. Polyanskiy

18.642 Topics in Mathematics with Applications in Finance
Prereq: 18.03, 18.06, and (18.05 or 18.600)
U (Fall)
3-0-9 units

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

18.650[J] Fundamentals of Statistics
Same subject as IDS.014[J]
Subject meets with 18.6501
Prereq: 6.3700 or 18.600
U (Fall, Spring)
4-0-8 units

A rapid introduction to the theoretical foundations of statistical methods that are useful in many applications. Covers a broad range of topics in a short amount of time with the goal of providing a rigorous and cohesive understanding of the modern statistical landscape. Mathematical language is used for intuition and basic derivations but not proofs. Main topics include: parametric estimation, confidence intervals, hypothesis testing, Bayesian inference, and linear and logistic regression. Additional topics may include: causal inference, nonparametric estimation, and classification.
Fall: P. Rigollet. Spring: A. Katsevich

18.6501 Fundamentals of Statistics
Subject meets with 18.650[J], IDS.014[J]
Prereq: 6.3700 or 18.600
G (Fall, Spring)
4-0-8 units

A rapid introduction to the theoretical foundations of statistical methods that are useful in many applications. Covers a broad range of topics in a short amount of time with the goal of providing a rigorous and cohesive understanding of the modern statistical landscape. Mathematical language is used for intuition and basic derivations but not proofs. Main topics include: parametric estimation, confidence intervals, hypothesis testing, Bayesian inference, and linear and logistic regression. Additional topics may include: causal inference, nonparametric estimation, and classification. Students in Course 18 must register for the undergraduate version, 18.650[J].
Fall: P. Rigollet. Spring: A. Katsevich

18.655 Mathematical Statistics
Prereq: (18.650[J] and (18.100A, 18.100A, 18.100P, or 18.100Q)) or permission of instructor
G (Spring)
3-0-9 units

Decision theory, estimation, confidence intervals, hypothesis testing. Introduces large sample theory. Asymptotic efficiency of estimates. Exponential families. Sequential analysis. Prior exposure to both probability and statistics at the university level is assumed.
P. Kempthorne

18.656[J] Mathematical Statistics: a Non-Asymptotic Approach
Same subject as 9.521[J], IDS.160[J]
Prereq: (6.7700[J], 18.06, and 18.6501) or permission of instructor
G (Spring)
3-0-9 units

See description under subject 9.521[J].
S. Rakhlin, P. Rigollet

18.657 Topics in Statistics
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units
Can be repeated for credit.

Topics vary from term to term.
P. Rigollet

18.675 Theory of Probability
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q
G (Fall)
3-0-9 units

Sums of independent random variables, central limit phenomena, infinitely divisible laws, Levy processes, Brownian motion, conditioning, and martingales. Prior exposure to probability (e.g., 18.600) recommended.
Y. Shenfeld

18.676 Stochastic Calculus
Prereq: 18.675
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Introduction to stochastic processes, building on the fundamental example of Brownian motion. Topics include Brownian motion, continuous parameter martingales, Ito's theory of stochastic differential equations, Markov processes and partial differential equations, and may also include local time and excursion theory. Students should have familiarity with Lebesgue integration and its application to probability.
N. Sun

18.677 Topics in Stochastic Processes
Prereq: 18.675
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units
Can be repeated for credit.

Topics vary from year to year.
A. Borodin

Algebra and Number Theory

18.700 Linear Algebra
Prereq: Calculus II (GIR)
U (Fall)
3-0-9 units. REST
Credit cannot also be received for 6.C06[J], 18.06, 18.C06[J], ES.1806

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.
V. Kac

18.701 Algebra I
Prereq: 18.100A, 18.100B, 18.100P, 18.100Q, 18.090, or permission of instructor
U (Fall)
3-0-9 units

18.701-18.702 is more extensive and theoretical than the 18.700-18.703 sequence. Experience with proofs necessary. 18.701 focuses on group theory, geometry, and linear algebra.
H. Cohn

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

Continuation of 18.701. Focuses on group representations, rings, ideals, fields, polynomial rings, modules, factorization, integers in quadratic number fields, field extensions, and Galois theory.
A. Negut

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

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, (18.06 and 18.703), or (18.700 and 18.703)
U (Fall)
3-0-9 units

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.
K. Vashaw

18.705 Commutative Algebra
Prereq: 18.702
G (Fall)
3-0-9 units

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

18.706 Noncommutative Algebra
Prereq: 18.702
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Topics may include Wedderburn theory and structure of Artinian rings, Morita equivalence and elements of category theory, localization and Goldie's theorem, central simple algebras and the Brauer group, representations, polynomial identity rings, invariant theory growth of algebras, Gelfand-Kirillov dimension.
R. Bezrukavnikov

18.708 Topics in Algebra
Prereq: 18.705
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units
Can be repeated for credit.

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

18.715 Introduction to Representation Theory
Prereq: 18.702 or 18.703
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Algebras, representations, Schur's lemma. Representations of SL(2). Representations of finite groups, Maschke's theorem, characters, applications. Induced representations, Burnside's theorem, Mackey formula, Frobenius reciprocity. Representations of quivers.
G. Lusztig

18.721 Introduction to Algebraic Geometry
Prereq: 18.702 and 18.901
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Spring)
3-0-9 units

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

18.725 Algebraic Geometry I
Prereq: None. *Coreq: 18.705*
G (Fall)
3-0-9 units

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.
D. Maulik

18.726 Algebraic Geometry II
Prereq: 18.725
G (Spring)
3-0-9 units

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.
D. Maulik

18.727 Topics in Algebraic Geometry
Prereq: 18.725
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units
Can be repeated for credit.

Topics vary from year to year.
A. Negut

18.737 Algebraic Groups
Prereq: 18.705
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

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 etale cohomology. Some results from algebraic geometry are stated without proof.
J.-L. Kim

18.745 Lie Groups and Lie Algebras I
Prereq: (18.701 or 18.703) and (18.100A, 18.100B, 18.100P, or 18.100Q)
G (Fall)
3-0-9 units

Covers fundamentals of the theory of Lie algebras and related groups. Topics may include theorems of Engel and Lie; enveloping algebra, Poincare-Birkhoff-Witt theorem; classification and construction of semisimple Lie algebras; the center of their enveloping algebras; elements of representation theory; compact Lie groups and/or finite Chevalley groups.
V. G. Kac

18.747 Infinite-dimensional Lie Algebras
Prereq: 18.745
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

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

18.748 Topics in Lie Theory
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units
Can be repeated for credit.

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

18.755 Lie Groups and Lie Algebras II
Prereq: 18.745 or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

A more in-depth treatment of Lie groups and Lie algebras. Topics may include homogeneous spaces and groups of automorphisms; representations of compact groups and their geometric realizations, Peter-Weyl theorem; invariant differential forms and cohomology of Lie groups and homogeneous spaces; complex reductive Lie groups, classification of real reductive groups.
Z. Yun

18.757 Representations of Lie Groups
Prereq: 18.745 or 18.755
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

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.
P. I. Etingof

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

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

18.782 Introduction to Arithmetic Geometry
Prereq: 18.702
Acad Year 2024-2025: U (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units

Exposes students to arithmetic geometry, motivated by the problem of finding rational points on curves. Includes an introduction 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.
S. Chidambaram

18.783 Elliptic Curves
Subject meets with 18.7831
Prereq: 18.702, 18.703, or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (Fall)
3-0-9 units

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

18.7831 Elliptic Curves
Subject meets with 18.783
Prereq: 18.702, 18.703, or permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Fall)
3-0-9 units

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. Students in Course 18 must register for the undergraduate version, 18.783.
A. Sutherland

18.784 Seminar in Number Theory
Prereq: 18.701 or (18.703 and (18.06 or 18.700))
U (Spring)
3-0-9 units

Topics vary from year to year. Students present and discuss the subject matter. Instruction and practice in written and oral communication provided. Enrollment limited.
A. Landesman

18.785 Number Theory I
Prereq: None. *Coreq: 18.705*
G (Fall)
3-0-9 units

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. Adeles 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 units

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.
A. Sutherland

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

Topics vary from year to year.
W. Zhang

Mathematics Laboratory

18.821 Project Laboratory in Mathematics
Prereq: Two mathematics subjects numbered 18.100 or above
U (Fall, Spring)
3-6-3 units. 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.
Fall: A. Negut. Spring: L. Piccirillo

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

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

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

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

18.899 Internship in Mathematics (New)
Prereq: None
G (Fall, Spring, Summer)
Units arranged [P/D/F]

Provides academic credit for students pursuing internships to gain practical experience applications of mathematical concepts and methods as related to their field of research.
J. Kelner, D. Maulik, Z. Yun

Topology and Geometry

18.900 Geometry and Topology in the Plane
Prereq: 18.03 or 18.06
U (Spring)
3-0-9 units

Introduction to selected aspects of geometry and topology, using concepts that can be visualized easily. Mixes geometric topics (such as hyperbolic geometry or billiards) and more topological ones (such as loops in the plane). Suitable for students with no prior exposure to differential geometry or topology.
P. Seidel

18.901 Introduction to Topology
Subject meets with 18.9011
Prereq: 18.100A, 18.100B, 18.100P, 18.100Q, or permission of instructor
U (Fall, Spring)
3-0-9 units

Introduces topology, covering topics fundamental to modern analysis and geometry. Topological spaces and continuous functions, connectedness, compactness, separation axioms, covering spaces, and the fundamental group.
Fall: A. Pieloch. Spring: R. Jiang

18.9011 Introduction to Topology
Subject meets with 18.901
Prereq: 18.100A, 18.100B, 18.100P, 18.100Q, or permission of instructor
G (Fall, Spring)
3-0-9 units

Introduces topology, covering topics fundamental to modern analysis and geometry. Topological spaces and continuous functions, connectedness, compactness, separation axioms, covering spaces, and the fundamental group. Students in Course 18 must register for the undergraduate version, 18.901.
Fall: A. Pieloch. Spring: R. Jiang

18.904 Seminar in Topology
Prereq: 18.901
U (Spring)
3-0-9 units

Topics vary from year to year. Students present and discuss the subject matter. Instruction and practice in written and oral communication provided. Enrollment limited.
A. Ward

18.905 Algebraic Topology I
Prereq: 18.901 and (18.701 or 18.703)
G (Fall)
3-0-9 units

Singular homology, CW complexes, universal coefficient and Künneth theorems, cohomology, cup products, Poincaré duality.
D. Alvarez-Gavela

18.906 Algebraic Topology II
Prereq: 18.905 and (18.101 or 18.965)
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units

Continues the introduction to Algebraic Topology from 18.905. Topics include basic homotopy theory, spectral sequences, characteristic classes, and cohomology operations.
T. S. Mrowka

18.917 Topics in Algebraic Topology
Prereq: 18.906
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: G (Spring)
3-0-9 units
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.
Information: T. Schlank

18.919 Graduate Topology Seminar
Prereq: 18.906
G (Spring)
3-0-9 units

Study and discussion of important original papers in the various parts of topology. Open to all students who have taken 18.906 or the equivalent, not only prospective topologists.
T. Schlank

18.937 Topics in Geometric Topology
Prereq: Permission of instructor
Acad Year 2024-2025: G (Fall, Spring)
Acad Year 2025-2026: Not offered
3-0-9 units
Can be repeated for credit.

Content varies from year to year. Introduces new and significant developments in geometric topology.
T. S. Mrowka

18.950 Differential Geometry
Subject meets with 18.9501
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
U (Fall)
3-0-9 units

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.
G. Franz

18.9501 Differential Geometry
Subject meets with 18.950
Prereq: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
G (Fall)
3-0-9 units

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. Students in Course 18 must register for the undergraduate version, 18.950.
G. Franz

18.952 Theory of Differential Forms
Prereq: 18.101 and (18.700 or 18.701)
U (Spring)
Not offered regularly; consult department
3-0-9 units

Multilinear algebra: tensors and exterior forms. Differential forms on R^n: exterior differentiation, the pull-back operation and the Poincaré lemma. Applications to physics: Maxwell's equations from the differential form perspective. Integration of forms on open sets of 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 units

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, recommended.
W. Minicozzi

18.966 Geometry of Manifolds II
Prereq: 18.965
G (Spring)
3-0-9 units

Continuation of 18.965, focusing 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.
T. Colding

18.968 Topics in Geometry
Prereq: 18.965
Acad Year 2024-2025: G (Spring)
Acad Year 2025-2026: Not offered
3-0-9 units
Can be repeated for credit.

Content varies from year to year.
P. Seidel

18.979 Graduate Geometry Seminar
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-0-9 units
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: (18.06, 18.700, or 18.701) and (18.100A, 18.100B, 18.100P, or 18.100Q)
U (Spring)
3-0-9 units

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. Enrollment limited.
Q. Deng

18.999 Research in Mathematics
Prereq: Permission of instructor
G (Fall, IAP, 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: W. Minicozzi

18.C20[J] Introduction to Computational Science and Engineering
Same subject as 9.C20[J], 16.C20[J], CSE.C20[J]
Prereq: 6.100A; *Coreq: 8.01 and 18.01*
U (Fall, Spring; second half of term)
2-0-4 units
Credit cannot also be received for 6.100B

See description under subject 16.C20[J].
D. L. Darmofal, N. Seethapathi

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

Focuses on algorithms and techniques for writing and using modern technical software in a job, lab, or research group environment that may consist of interdisciplinary teams, where performance may be critical, and where the software needs to be flexible and adaptable. Topics include automatic differentiation, matrix calculus, scientific machine learning, parallel and GPU computing, and performance optimization with introductory applications to climate science, economics, agent-based modeling, and other areas. Labs and projects focus on performant, readable, composable algorithms, and software. Programming will be in Julia. Expects students to have some familiarity with Python, Matlab, or R. No Julia experience necessary.
A. Edelman, R. Ferrari, B. Forget, C. Leiseron,Y. Marzouk, J. Williams

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: W. Minicozzi

18.TAC Classroom Teaching in Mathematics (New)
Prereq: None
G (Fall, IAP, Spring)
12-0-0 units

For classroom training in Mathematics, in cases where teaching assignment is to fulfill academic teaching requirement by the department.
Staff

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

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

18.S096 Special Subject in Mathematics
Prereq: Permission of instructor
U (Spring)
Units arranged
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.
Staff

18.S097 Special Subject in Mathematics
Prereq: Permission of instructor
U (IAP)
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.
Staff

18.S190 Special Subject in Mathematics
Prereq: Permission of instructor
U (IAP)
Units arranged
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.
Staff

18.S191 Special Subject in Mathematics
Prereq: Permission of instructor
Acad Year 2024-2025: Not offered
Acad Year 2025-2026: U (IAP)
Units arranged
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.
Staff

18.S995 Special Subject in Mathematics
Prereq: Permission of instructor
G (Spring)
Units arranged
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.
Staff

18.S996 Special Subject in Mathematics
Prereq: Permission of instructor
G (Spring)
Units arranged
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.
Staff

18.S997 Special Subject in Mathematics
Prereq: Permission of instructor
G (Spring)
Units arranged
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.
Staff

18.S998 Special Subject in Mathematics
Prereq: Permission of instructor
G (Spring)
Units arranged
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.
Staff