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). 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 (http://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 (http://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...
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 (http://catalog.mit.edu/degree-charts/mathematics-course-18/#theoreticalmathematicaltext).

**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 or 18.700) because it is so broadly used, and discrete mathematics (18.062) 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 Automata, Computability, and Complexity) and algorithms (18.410) 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 (6.031, 6.033, 6.034, or 6.036) where mathematical issues may also arise. More details can be found on the degree chart (http://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. 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 (http://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 120-125 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 these degrees are described on the department’s website (http://math.mit.edu/academics/grad/timeline). In outline, they consist of a language requirement, an oral qualifying examination, a thesis proposal, completion of a minimum of 132 units (11 graduate subjects), and a thesis containing original research in mathematics.

**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.

**Faculty and Teaching Staff**

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Professor of Mathematics

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Professor of Computer Science
Member, Health Sciences and Technology Faculty

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Member, Institute for Data, Systems, and Society

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Dean, School of Science

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Gilbert Strang, PhD
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Norbert Wiener Professor of Mathematics

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Associate Professor of Mathematics

Laurent Demanet, PhD
Class of 1954 Career Development Professor
Associate Professor of Mathematics

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Mark Hyman, Jr. Career Development Professor
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Member, Institute for Data, Systems, and Society

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Bobby L. E. Wilson, PhD
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Instructor of Applied Mathematics

Pedro Sáenz Hervías, PhD
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Instructor of Applied Mathematics

Afonso Sousa Bandeira, PhD
Instructor of Applied Mathematics

Norbert Stoop, PhD
Instructor of Applied Mathematics

Vladislav Voroninski, PhD
Instructor of Applied Mathematics

Yinghui Wang, PhD
Instructor of Applied Mathematics

Yuan Zhou, PhD
Instructor of Applied Mathematics

**Instructors of Pure Mathematics**

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Instructor of Pure Mathematics

Vincent Genest, PhD
Instructor of Pure Mathematics

Boris Hanin, PhD
Instructor of Pure Mathematics

Kyler B. Siegel, PhD
Instructor of Pure Mathematics

Linh My Truong, PhD
Instructor of Pure Mathematics

Bohua Zhan, PhD
Instructor of Pure Mathematics

**Research Staff**

**Principal Research Scientists**

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Principal Research Scientist of Mathematics
Research Scientists
David I. Spivak, PhD
Research Scientist of Mathematics

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Richard Dudley, PhD
Professor Emeritus of Mathematics

Daniel Z. Freedman, PhD
Professor Emeritus of Mathematics
Professor Emeritus of Physics

Harvey P. Greenspan, PhD
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Isadore Manuel Singer, PhD
Institute Professor Emeritus
Professor Emeritus of Mathematics

Harold Stark, PhD
Professor Emeritus of Mathematics

Alar Toomre, PhD
Professor Emeritus of Mathematics

General Mathematics

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

Fall: J. Speck
Spring: Information: J. W. Bush

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, 18.014, CC.181A, 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 4 or 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.
G. Staffilani
18.014 Calculus with Theory
Prereq: None
U (Fall)
5-0-7 units. CALC I
Credit cannot also be received for 18.01, 18.01A, ES.1801, ES.181A

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

18.02 Calculus
Prereq: Calculus I (GIR)
U (Fall, Spring)
5-0-7 units. CALC II
Credit cannot also be received for 18.022, 18.024, CC.1802, CC.182A, ES.1802, ES.182A

Calculus of several variables. Vector algebra in 3-space, determinants, matrices. 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.
P. I. Etingof

18.02A Calculus
Prereq: Calculus I (GIR)
U (Fall, IAP, Spring)
5-0-7 units. CALC II
Credit cannot also be received for 18.02, 18.022, 18.024, CC.1802, CC.182A, 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.
N. Stoop

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

Calculus of several variables. Topics as in 18.02 but with more focus on mathematical concepts. Vector algebra, dot product, matrices, determinant. Functions of several variables, continuity, differentiability, derivative. 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.
P. I. Etingof

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

Continues 18.014. Parallel to 18.02, but at a deeper level, emphasizing careful reasoning and understanding of proofs. Considerable emphasis on linear algebra and vector integral calculus.
M. McBreen

18.03 Differential Equations
Prereq: None. Coreq: Calculus II (GIR)
U (Fall, Spring)
5-0-7 units. REST
Credit cannot also be received for 18.034, CC.1803, ES.1803

Fall: J. Dunkel
Spring: L. Demanet
18.031 System Functions and the Laplace Transform
Prereq: 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: J. W. Bush

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

Covers much of the same material as 18.03 with more emphasis on theory. The point of view is rigorous and results are proven. Local existence and uniqueness of solutions.

T. Colding

18.04 Complex Variables with Applications
Prereq: Calculus II (GIR); 18.03 or 18.034
U (Spring)
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.

J. Orloff

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


D. A. Vogan

18.06 Linear Algebra
Prereq: Calculus II (GIR)
U (Fall, Spring)
4-0-8 units. REST
Credit cannot also be received for 18.700

Basic subject on matrix theory and linear algebra, emphasizing topics useful in other disciplines, including systems of equations, vector spaces, determinants, eigenvalues, singular value decomposition, and positive definite matrices. Applications to least-squares approximations, stability of differential equations, networks, Fourier transforms, and Markov processes. Uses MATLAB. Compared with 18.700, more emphasis on matrix algorithms and many applications.

Fall: C. Barwick
Spring: S. G. Johnson

18.062[J] Mathematics for Computer Science
Same subject as 6.042[J]
Prereq: Calculus I (GIR)
U (Fall, Spring)
5-0-7 units. REST
See description under subject 6.042[J].

F. T. Leighton, A. R. Meyer, A. Moitra

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

Reviews linear algebra with applications to life sciences, finance, 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 hidden Markov models. Students taking graduate version complete additional assignments.

G. Strang
18.0651 Matrix Methods in Data Analysis, Signal Processing, and Machine Learning (New)
Subject meets with 18.065
Prereq: 18.06
G (Spring)
3-0-9 units
Reviews linear algebra with applications to life sciences, finance, 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 hidden Markov models. Students taking graduate version complete additional assignments.
G. Strang

18.075 Methods for Scientists and Engineers
Subject meets with 18.0751
Prereq: Calculus II (GIR); 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 18.0751
Prereq: Calculus II (GIR); 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); 18.03 or 18.034
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: G. Strang
Spring: P. Saenz

18.0851 Computational Science and Engineering I
Subject meets with 18.085
Prereq: Calculus II (GIR); 18.03 or 18.034
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: G. Strang
Spring: P. Saenz

18.086 Computational Science and Engineering II
Subject meets with 18.0861
Prereq: Calculus II (GIR); 18.03 or 18.034
U (Spring)
3-0-9 units
H. Reid
18.0861 Computational Science and Engineering II
Subject meets with 18.086
Prereq: Calculus II (GIR); 18.03 or 18.034
G (Spring)
3-0-9 units


H. Reid

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: J. W. Bush

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: J. W. Bush

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: J. W. Bush

18.099 Independent Study
Prereq: Permission of instructor
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Studies (during IAP) or special individual reading (during regular terms). Arranged in consultation with individual faculty members and subject to departmental approval.

Information: J. W. Bush

Analysis

18.1001 Real Analysis
Subject meets with 18.100A
Prereq: Calculus II (GIR); or 18.014 and Coreq: Calculus II (GIR)
G (Fall, Spring)
3-0-9 units
Credit cannot also be received for 18.100B, 18.100P, 18.100Q

18.1002 Real Analysis
Subject meets with 18.100B
Prereq: Calculus II (GIR); or 18.014 and Coreq: Calculus II (GIR)
G (Fall, Spring)
3-0-9 units
Credit cannot also be received for 18.100A, 18.100Q

18.100A Real Analysis
Subject meets with 18.1001
Prereq: Calculus II (GIR); or 18.014 and Coreq: Calculus II (GIR)
U (Fall, Spring)
3-0-9 units
Credit cannot also be received for 18.100B, 18.100P, 18.100Q

18.100B Real Analysis
Subject meets with 18.1002
Prereq: Calculus II (GIR); or 18.014 and Coreq: Calculus II (GIR)
U (Fall, Spring)
3-0-9 units
Credit cannot also be received for 18.100A, 18.100Q
18.100P Real Analysis (New)
Prereq: Calculus II (GIR); or 18.014 and Coreq: Calculus II (GIR)
U (Spring)
4-0-11 units
Credit cannot also be received for 18.1001, 18.100A, 18.100B, 18.100Q
Enrollment limited in Options P and Q.

18.100Q Real Analysis (18.100C)
Prereq: Calculus II (GIR); or 18.014 and Coreq: 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

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

Fall: 18.100A: A. P. Mattuck
18.100B: D. Jerison
18.100Q: B. Wilson
Spring: 18.100A: R. Casals
18.100B: A. Lawrie
18.100P: T. Beck

18.101 Analysis and Manifolds
Subject meets with 18.101
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.06, 18.700, or 18.701
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. Students in Course 18 must register for the undergraduate version, 18.101.
V. W. Guillemin

18.1011 Analysis and Manifolds
Subject meets with 18.101
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.06, 18.700, or 18.701
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.
V. W. Guillemin

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

R. B. Melrose

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

R. B. Melrose

18.103 Fourier Analysis: Theory and Applications
Subject meets with 18.1031
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.06, 18.700, or 18.701
U (Fall)
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.
A. Lawrie
18.1031 Fourier Analysis: Theory and Applications
Subject meets with 18.103
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.06, 18.700, or 18.701
G (Fall)
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.
A. Lawrie

18.104 Seminar in Analysis
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q
U (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.
D. Jerison

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

T. Beck

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

T. Beck

18.116 Riemann Surfaces
Prereq: 18.112
Acad Year 2016-2017: G (Fall)
Acad Year 2017-2018: Not offered
3-0-9 units

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

18.117 Topics in Several Complex Variables
Prereq: 18.112, 18.965
Acad Year 2016-2017: G (Spring)
Acad Year 2017-2018: Not offered
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

18.125 Measure Theory and Analysis
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q
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.
S. Becker-Kahn
**18.137 Topics in Geometric Partial Differential Equations**  
Prereq: Permission of Instructor  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (Spring)  
3-0-9 units  
Can be repeated for credit.  
Topics vary from year to year.  
*Information: R. B. Melrose*

**18.152 Introduction to Partial Differential Equations**  
Subject meets with 18.1521  
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.06, 18.700, or 18.701  
U (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.  
*J. Speck*

**18.1521 Introduction to Partial Differential Equations**  
Subject meets with 18.152  
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.06, 18.700, or 18.701  
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.  
*J. Speck*

**18.156 Differential Analysis II**  
Prereq: 18.155  
G (Spring)  
3-0-9 units  
*Fall: R. B. Melrose  
Spring: S. Dyatlov*

**18.157 Introduction to Microlocal Analysis**  
Prereq: 18.155  
Acad Year 2016-2017: G (Spring)  
Acad Year 2017-2018: Not offered  
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 Schrödinger operators from the semi-classical perspective. Heavy emphasis placed on the symplectic geometric underpinnings of this subject.  
*V. W. Guillemin*

**18.158 Topics in Differential Equations**  
Prereq: 18.157  
G (Spring)  
3-0-9 units  
Can be repeated for credit.  
Topics vary from year to year.  
*G. Staffilani*

**18.175 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.  
*S. Sheffield*
18.176 Stochastic Calculus
Prereq: 18.175
G (Spring)
3-0-9 units
Introduction to stochastic processes with an emphasis on their relationship to other branches of analysis, especially partial differential equations. Topics include Brownian motion, continuous parameter martingales, Itô's theory of stochastic differential equations, Levy processes, and may also address Malliavin's calculus. Students should have familiarity with Lebesgue integration and its application to probability, as well knowledge of the Fourier transform and other basic tools of analysis.
D. W. Stroock

18.177 Topics in Stochastic Processes
Prereq: 18.175
G (Fall, Spring)
3-0-9 units
Can be repeated for credit.
Topics vary from year to year.
Fall: V. Gorin
Spring: E. Mossel

18.199 Graduate Analysis Seminar
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
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: Calculus II (GIR)
U (Fall)
4-0-11 units
Credit cannot also be received for 18.200A
Study of illustrative topics in discrete applied mathematics, including sorting algorithms, probability theory, information theory, coding theory, secret codes, generating functions, and linear programming. Instruction and practice in written communication provided. Enrollment limited.
M. X. Goemans

18.200A Principles of Discrete Applied Mathematics
Prereq: Calculus II (GIR)
U (Spring)
3-0-9 units
Credit cannot also be received for 18.200
Study of illustrative topics in discrete applied mathematics, including sorting algorithms, probability theory, information theory, coding theory, secret codes, generating functions, and linear programming.
P. W. Shor

18.204 Undergraduate Seminar in Discrete Mathematics
Prereq: 18.200 or 18.062[J]; 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.
Fall: T. McConville
Spring: Y. Wang

18.211 Combinatorial Analysis
Prereq: Calculus II (GIR); 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.
M. Rahman

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.
T. McConville

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.
R. P. Stanley
18.218 Topics in Combinatorics
Prereq: Permission of instructor
G (Spring)
3-0-9 units
Can be repeated for credit.
Topics vary from year to year.
A. Postnikov

18.219 Seminar in Combinatorics
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
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.
J. Fox

Continuous Applied Mathematics

18.300 Principles of Continuum Applied Mathematics
Prereq: Calculus II (GIR); 18.03 or 18.034
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.
L. Faria

18.303 Linear Partial Differential Equations: Analysis and Numerics
Prereq: 18.06 or 18.700
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.
S. G. Johnson

18.305 Advanced Analytic Methods in Science and Engineering
Prereq: 18.04, 18.075, or 18.112
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 18.034; 18.04, 18.075, or 18.112
G (Spring)
3-0-9 units
R. R. Rosales
18.327 Topics in Applied Mathematics  
Prereq: Permission of instructor  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: 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); 18.03 or 18.034  
U (Spring)  
3-0-9 units  
H. Reid

18.335[J] Introduction to Numerical Methods  
Same subject as 6.337[J]  
Prereq: 18.06, 18.700, or 18.701  
G (Spring)  
3-0-9 units  
Advanced introduction to numerical analysis. Surveys major topics that arise at various levels of solving classic numerical problems, such as systems of linear equations, eigenvalue equations, and least squares problems. Specific topics include matrix factorizations (QR, SVD, LU, Cholesky); direct and iterative methods to solve linear systems (Gaussian elimination, Krylov subspace methods); numerical algorithms to solve eigenvalue equations (Rayleigh quotient iteration, inverse iteration, QR algorithm); conditioning of problems and stability of algorithms; and floating point arithmetic.  
W. Shin

Same subject as 6.335[J]  
Prereq: 6.336[J], 16.920[J], 18.085, 18.335[J], or permission of instructor  
G (Fall)  
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.  
C. Perez

18.337[J] Parallel Computing  
Same subject as 6.338[J]  
Prereq: 18.06, 18.700, or 18.701  
G (Fall)  
3-0-9 units  
Interdisciplinary introduction to computing with Julia. Covers scientific computing and data analysis problems. Combines knowledge from computer science and computational science illustrating Julia’s new approach to scientific computing. Sample scientific computing topics include dense and sparse linear algebra, Fourier transforms, data handling, and N-body problems. Provides direct experience with programming traditional-style supercomputing as well as working with modern cloud computing stacks.  
A. Edelman

18.338 Eigenvalues of Random Matrices  
Prereq: 18.701 or permission of instructor  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (Spring)  
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 MATLAB helpful, but not required.  
A. Edelman
18.352[J] Nonlinear Dynamics: The Natural Environment
Same subject as 12.009[J]
Prereq: Physics I (GIR), Calculus II (GIR); Coreq: 18.03
U (Spring)
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: 18.03 or 18.034; Physics II (GIR)
U (Fall)
3-0-9 units

See description under subject 12.006[J].
P-T. Brun

18.354[J] Nonlinear Dynamics: Continuum Systems
Same subject as 1.062[J], 12.207[J]
Subject meets with 18.3541
Prereq: 18.03 or 18.034; Physics II (GIR)
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.
P. Pearce

18.3541 Nonlinear Dynamics: Continuum Systems
Subject meets with 1.062[J], 12.207[J], 18.354[J]
Prereq: 18.03 or 18.034; Physics II (GIR)
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].
P. Pearce

18.355 Fluid Mechanics
Prereq: 18.354[J], 2.25, or 12.800
Acad Year 2016-2017: G (Fall)
Acad Year 2017-2018: 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: 18.354[J], 18.355, 12.800, 2.25, or permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
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 (New)
Same subject as 1.686[J], 2.033[J]
Subject meets with 1.068
Prereq: Permission of instructor
Acad Year 2016-2017: G (Spring)
Acad Year 2017-2018: Not offered
3-0-9 units

See description under subject 1.686[J].
L. Bourouiba
18.369 Mathematical Methods in Nanophotonics
Prereq: 18.305 or permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: 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 solvable. The basis for understanding optical phenomena such as photonic crystals and band gaps, anomalous diffraction, mechanisms for optical confinement, optical fibers (new and old), nonlinearities, and integrated optical devices. Methods covered include linear algebra and eigensystems for Maxwell’s equations, symmetry groups and representation theory, Bloch’s theorem, numerical eigensolver methods, time and frequency-domain computation, perturbation theory, and coupled-mode theories.
S. G. Johnson

18.376[J] Wave Propagation
Same subject as 1.138[J], 2.062[J]
Prereq: 2.003[J], 18.075
Acad Year 2016-2017: G (Spring)
Acad Year 2017-2018: Not offered
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 2016-2017: Not offered
Acad Year 2017-2018: 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.
T. R. Akylas

18.384 Undergraduate Seminar in Physical Mathematics
Prereq: 18.300, 18.353[J], 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.
L. Faria

18.385[J] Nonlinear Dynamics and Chaos
Same subject as 2.036[J]
Prereq: 18.03 or 18.034
Acad Year 2016-2017: G (Fall)
Acad Year 2017-2018: Not offered
3-0-9 units

R. R. Rosales

18.395 Group Theory with Applications to Physics
Prereq: 8.321
G (Fall)
Not offered regularly; consult department
3-0-9 units

Selection of topics from the theory of finite groups, Lie groups, and group representations, motivated by quantum mechanics and particle physics. 8.322 and 8.323 helpful.
D. Z. Freedman
18.396[J] Supersymmetric Quantum Field Theories
Same subject as 8.831[J]
Prereq: Permission of instructor
G (Spring)
3-0-9 units
Can be repeated for credit.
Topics selected from the following: SUSY algebras and their particle representations; Weyl and Majorana spinors; Lagrangians of basic four-dimensional SUSY theories, both rigid SUSY and supergravity; supermultiplets of fields and superspace methods; renormalization properties, and the non-renormalization theorem; spontaneous breakdown of SUSY; and phenomenological SUSY theories. Some prior knowledge of Noether's theorem, derivation and use of Feynman rules, l-loop renormalization, and gauge theories is essential.
J. Thaler

Theoretical Computer Science

18.400[J] Automata, Computability, and Complexity
Same subject as 6.045[J]
Prereq: 6.042[J]
U (Spring)
4-0-8 units
See description under subject 6.045[J].
S. Aaronson

18.404 Theory of Computation
Subject meets with 6.840[J], 18.4041[J]
Prereq: 18.200 or 18.062[J]
U (Fall)
4-0-8 units
A more extensive and theoretical treatment of the material in 6.045[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 6.841[J]
Prereq: 18.404
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
3-0-9 units
D. Moshkovitz

18.408 Topics in Theoretical Computer Science
Prereq: Permission of instructor
Acad Year 2016-2017: G (Fall)
Acad Year 2017-2018: 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.
Information: M. X. Goemans

18.410[J] Design and Analysis of Algorithms
Same subject as 6.046[J]
Prereq: 6.006
U (Fall, Spring)
4-0-8 units
See description under subject 6.046[J].
E. Demaine, M. Goemans
18.415[J] Advanced Algorithms
Same subject as 6.854[J]
Prereq: 6.041B, 6.042[J], or 18.600; 6.046[J]
G (Fall)
5-0-7 units
See description under subject 6.854[J].
A. Moitra, D. R. Karger

18.416[J] Randomized Algorithms
Same subject as 6.856[J]
Prereq: 6.854[J], 6.041B or 6.042[J]
Acad Year 2016-2017: G (Spring)
Acad Year 2017-2018: Not offered
5-0-7 units
See description under subject 6.856[J].
D. R. Karger

18.417 Introduction to Computational Molecular Biology
Prereq: 6.01, 6.006, or permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units
Introduces the basic computational methods used to model and predict the structure of biomolecules (proteins, DNA, RNA). Covers classical techniques in the field (molecular dynamics, Monte Carlo, dynamic programming) to more recent advances in analyzing and predicting RNA and protein structure, ranging from Hidden Markov Models and 3-D lattice models to attribute Grammars and tree Grammars.
Information: B. Berger

18.418 Topics in Computational Molecular Biology
Prereq: 18.417, 6.047, or permission of instructor
G (Spring)
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 SIGACT International Conference on Computational Molecular Biology (RECOMB). Topics include original research (both theoretical and experimental) in comparative genomics, sequence and structure analysis, molecular evolution, proteomics, gene expression, transcriptional regulation, and biological networks. Recent research by course participants also covered. Participants will be expected to present either group or individual projects to the class.
B. Berger

18.424 Seminar in Information Theory
Prereq: 18.05, 18.600, or 6.041B; 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.
P. W. Shor

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

18.434 Seminar in Theoretical Computer Science
Prereq: 18.410[J]
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.
Z. Remscrim

18.435[J] Quantum Computation
Same subject as 2.111[J], 8.370[J]
Prereq: Permission of instructor
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, E. Farhi, S. Lloyd, P. Shor

18.436[J] Quantum Information Science
Same subject as 6.443[J], 8.371[J]
Prereq: 18.435[J]
G (Spring)
3-0-9 units
See description under subject 8.371[J].
I. Chuang
18.437[J] Distributed Algorithms
Same subject as 6.852[J]
Prereq: 6.046[J]
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3.0-9 units
See description under subject 6.852[J].
N. A. Lynch

18.453 Combinatorial Optimization
Subject meets with 18.4531
Prereq: 18.06, 18.700, or 18.701
Acad Year 2016-2017: U (Spring)
Acad Year 2017-2018: 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.
M. X. Goemans

18.4531 Combinatorial Optimization
Subject meets with 18.453
Prereq: 18.06, 18.700, or 18.701
Acad Year 2016-2017: G (Spring)
Acad Year 2017-2018: 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.
M. X. Goemans

18.455 Advanced Combinatorial Optimization
Prereq: 18.453 or permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: 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

Logic

18.504 Seminar in Logic
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.06, 18.510, 18.700, or 18.701
Acad Year 2016-2017: U (Spring)
Acad Year 2017-2018: Not offered
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 2016-2017: Not offered
Acad Year 2017-2018: U (Fall)
3.0-9 units
H. Cohn

18.515 Mathematical Logic
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3.0-9 units
Information: B. Poonen
**Probability and Statistics**

**18.600 Probability and Random Variables**  
Prereq: Calculus II (GIR)  
U (Fall, Spring)  
3-0-9 units. REST  

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: E. Mossel*  
*Spring: S. Sheffield*

**18.615 Introduction to Stochastic Processes**  
Prereq: 18.600 or 6.041B  
G (Spring)  
3-0-9 units  

*A. Bufetov*

**18.642 Topics in Mathematics with Applications in Finance**  
Prereq: 18.03; 18.06; 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 Statistics for Applications**  
Subject meets with 18.650  
Prereq: 18.600 or 6.041B  
G (Fall, Spring)  
3-0-9 units  

A broad treatment of statistics, concentrating on specific statistical techniques used in science and industry. Topics: hypothesis testing and estimation. Confidence intervals, chi-square tests, nonparametric statistics, analysis of variance, regression, correlation, decision theory, and Bayesian statistics. Students in Course 18 must register for the undergraduate version, 18.650.  
*Fall: P. Rigollet*  
*Spring: P. Kempthorne*

**18.651 Statistics for Applications**  
Subject meets with 18.650  
Prereq: 18.600 or 6.041B  
G (Fall, Spring)  
3-0-9 units  

A broad treatment of statistics, concentrating on specific statistical techniques used in science and industry. Topics: hypothesis testing and estimation. Confidence intervals, chi-square tests, nonparametric statistics, analysis of variance, regression, correlation, decision theory, and Bayesian statistics. Students in Course 18 must register for the undergraduate version, 18.650.  
*Fall: P. Rigollet*  
*Spring: P. Kempthorne*

**18.655 Mathematical Statistics**  
Prereq: 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.  
*P. Kempthorne*

**18.657 Topics in Statistics**  
Prereq: Permission of instructor  
G (Spring)  
3-0-9 units  

Can be repeated for credit.  
Topics vary from term to term.  
*P. Rigollet*

**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 18.06  

Vector spaces, systems of linear equations, bases, linear independence, matrices, determinants, eigenvalues, inner products, quadratic forms, and canonical forms of matrices. More emphasis on theory and proofs than in 18.06.  
*C. Xu*
18.701 Algebra I  
Prereq: 18.100A, 18.100B, 18.100P, 18.100Q, or permission of instructor  
U (Fall)  
3-0-9 units  
See description under subject *UNKNOWN*.  
M. Artin

18.702 Algebra II  
Prereq: 18.701  
U (Spring)  
3-0-9 units  
More extensive and theoretical than the 18.700-18.703 sequence. Experience with proofs necessary. First term: group theory, geometry, and linear algebra. Second term: group representations, rings, ideals, fields, polynomial rings, modules, factorization, integers in quadratic number fields, field extensions, Galois theory.  
M. Artin

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

18.704 Seminar in Algebra  
Prereq: 18.701; or 18.06, 18.703; or 18.700, 18.703  
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. Some experience with proofs required.  
Enrollment limited.  
V. G. Kac

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.  
A. Negut

18.706 Noncommutative Algebra  
Prereq: 18.702  
Acad Year 2016-2017: G (Spring)  
Acad Year 2017-2018: Not offered  
3-0-9 units  
Topics may include one or more of the following: Coxeter groups, Hecke algebras, their canonical bases and their representations.  
G. Lusztig

18.708 Topics in Algebra  
Prereq: 18.705  
Acad Year 2016-2017: G (Fall)  
Acad Year 2017-2018: Not offered  
3-0-9 units  
Can be repeated for credit.  
Topics vary from year to year.  
Information: P. I. Etingof

18.715 Introduction to Representation Theory  
Prereq: 18.702 or 18.703  
Acad Year 2016-2017: G (Fall)  
Acad Year 2017-2018: Not offered  
3-0-9 units  
B. Poonen

18.721 Introduction to Algebraic Geometry  
Prereq: 18.702, 18.901  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: U (Spring)  
3-0-9 units  
Presents basic examples of complex algebraic varieties, affine and projective algebraic geometry, sheaves, cohomology.  
M. Artin
18.725 Algebraic Geometry I
Prereq: None. Coreq: 18.705
G (Fall)
3-0-9 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.
A. Pixton

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 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3-0-9 units
Can be repeated for credit.
Topics vary from year to year.
Information: D. A. Vogan

18.727 Algebraic Groups
Prereq: 18.705
Acad Year 2016-2017: G (Fall)
Acad Year 2017-2018: 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.
G. Lusztig

18.745 Introduction to Lie Algebras
Prereq: 18.701 or 18.703
G (Fall)
3-0-9 units
Topics may include structure of finite-dimensional Lie algebras; theorems of Engel and Lie; Cartan subalgebras and regular elements; trace form and Cartan's criterion; Chevalley's conjugacy theorem; classification and construction of semisimple Lie algebras; Weyl group; universal enveloping algebra and the Casimir operator; Weyl's complete reducibility theorem, Levi and Maltsev theorems; Verma modules; classification of irreducible finite-dimensional representations of semisimple Lie algebras; Weyl's character and dimension formulas.
V. G. Kac

18.746 Infinite-dimensional Lie Algebras
Prereq: 18.745
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
3-0-9 units
Topics vary from year to year.
P. I. Etingof

18.747 Topics in Lie Theory
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3-0-9 units
Can be repeated for credit.
Topics vary from year to year.
P. I. Etingof

18.755 Introduction to Lie Groups
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.700 or 18.701
G (Fall)
3-0-9 units
A general introduction to manifolds and Lie groups. The role of Lie groups in mathematics and physics. Exponential mapping. Correspondence with Lie algebras. Homogeneous spaces and transformation groups. Adjoint representation. Covering groups. Automorphism groups. Invariant differential forms and cohomology of Lie groups and homogeneous spaces. 18.101 recommended but not required.
S. A. Altug
18.757 Representations of Lie Groups  
Prereq: 18.745 or 18.755  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (Spring)  
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.  
L. Rider

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.  
A. Negut

18.782 Introduction to Arithmetic Geometry  
Prereq: 18.702  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: U (Fall)  
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.  
A. Sutherland

18.783 Elliptic Curves  
Subject meets with 18.7831  
Prereq: None. Coreq: 18.702, 18.703, or permission of instructor  
Acad Year 2016-2017: U (Spring)  
Acad Year 2017-2018: Not offered  
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: None. Coreq: 18.702, 18.703, or permission of instructor  
Acad Year 2016-2017: G (Spring)  
Acad Year 2017-2018: Not offered  
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

18.784 Seminar in Number Theory  
Prereq: 18.06; 18.100A, 18.100B, 18.100P, or 18.100Q  
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.  
D. Maulik

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.  
A. Sutherland

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.  
C. C. Tsai
18.787 Topics in Number Theory
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Fall)
3-0-9 units
Can be repeated for credit.
Topics vary from year to year.
B. Poonen

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: D. A. Vogan
Spring: R. Bezrukavnikov

Topological and Geometry

18.901 Introduction to Topology
Subject meets with 18.901
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, and selected further topics such as function spaces, embedding theorems, dimension theory, or covering spaces and the fundamental group.
Fall: M. Hoyois
Spring: T. Walpuski

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, and selected further topics such as function spaces, embedding theorems, dimension theory, or covering spaces and the fundamental group. Students in Course 18 must register for the undergraduate version, 18.901.
Fall: M. Hoyois
Spring: T. Walpuski

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

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

18.906 Algebraic Topology II
Prereq: 18.905
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.
H. R. Miller
18.917 Topics in Algebraic Topology
Prereq: 18.906
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.
C. Barwick

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

18.937 Topics in Geometric Topology
Prereq: Permission of instructor
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: G (Spring)
3-0-9 units
Can be repeated for credit.
Content varies from year to year. Introduces new and significant developments in geometric topology.
E. Murphy

18.950 Differential Geometry
Subject meets with 18.9501
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.06, 18.700, or 18.701
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.
H. Macbeth

18.9501 Differential Geometry
Subject meets with 18.950
Prereq: 18.100A, 18.100B, 18.100P, or 18.100Q; 18.06, 18.700, or 18.701
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.
H. Macbeth

18.952 Theory of Differential Forms
Prereq: 18.101; 18.700 or 18.701
Acad Year 2016-2017: Not offered
Acad Year 2017-2018: U (Spring)
3-0-9 units
Multilinear algebra: tensors and exterior forms. Differential forms on $\mathbb{R}^n$: 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 $\mathbb{R}^n$. The change of variables formula revisited. The degree of a differentiable mapping. Differential forms on manifolds and De Rham theory. Integration of forms on manifolds and Stokes’ theorem. The push-forward operation for forms. Thom forms and intersection theory. Applications to differential topology.
V. W. Guillemin

18.965 Geometry of Manifolds I
Prereq: 18.101, 18.950 or 18.952
G (Fall)
3-0-9 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.
H. Macbeth
18.966 Geometry of Manifolds II  
Prereq: 18.965  
G (Spring)  
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, is recommended.  
Fall: T. Walpuski  
Spring: W. Minicozzi

18.968 Topics in Geometry  
Prereq: 18.965  
Acad Year 2016-2017: G (Fall)  
Acad Year 2017-2018: Not offered  
3-0-9 units  
Can be repeated for credit.  
Content varies from year to year.  
T. Colding

18.979 Graduate Geometry Seminar  
Prereq: Permission of instructor  
Acad Year 2016-2017: Not offered  
Acad Year 2017-2018: G (Spring)  
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: 18.101, 18.102, 18.103, or 18.112  
U (Fall)  
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.  
R. Hynd

18.999 Research in Mathematics  
Prereq: Permission of instructor  
G (Fall, Spring, Summer)  
Units arranged  
Can be repeated for credit.  
Opportunity for study of graduate-level topics in mathematics under the supervision of a member of the department. For graduate students desiring advanced work not provided in regular subjects.  
Information: W. Minicozzi

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: J. W. Bush

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 (IAP, 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. 18.S097 is graded P/D/F.  
Information: J. W. Bush
18.S995-18.S998 Special Subject in Mathematics
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
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.

Information: J. W. Bush