1995 MIT

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BACHELOR OF SCIENCE IN MATHEMATICS, COURSE XVIII

General Mathematics Option

This option is the one followed by most students who major in mathematics. Besides the General Institute Requirements, the requirements consist of 18.03 Differential Equations, or 18.034 Differential Equations, and eight 12–unit subjects in Course 18 of essentially different content, including at least six advanced subjects (first decimal digit one or higher). This leaves available 84 units of unrestricted electives. The requirements are flexible in order to accommodate several categories of students: students who pursue programs that combine mathematics with a related field (such as physics, economics, or management); students interested in both theoretical and applied mathematics; and students who use mathematics as a general Institute major.

Applied Mathematics Option

Applied mathematics is the mathematical study of general scientific concepts, principles, and phenomena that, because of their widespread occurrence and application, relate or unify various disciplines. The core of the program at MIT concerns the following principles and their mathematical formulations: propagation, equilibrium, stability, optimization, cybernetics, statistics, and random processes.

Sophomores interested in applied mathematics typically survey the field by enrolling in 18.310 and 18.311 Principles of Applied Mathematics. Subject 18.310, given only in the first term, is devoted to the discrete aspects of the study and may be taken concurrently with 18.03. Subject 18.311, given only in the second 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. Naturally, there is a good deal of overlap; for example, such subjects as probability or numerical analysis have both discrete and continuous aspects.

Bachelor of Science in Mathematics/Course XVIII—Applied Mathematics Option
CLASS OF 1996 or earlier: See Notes on Course XVIII below.

General Institute Requirements (GIRs)	**Subjects**
Science Requirement	6
Humanities, Arts, and Social Sciences Requirement	8
Restricted Electives in Science and Technology (REST) Requirement [one subject can be satisfied by 18.03 or 18.034 in the Departmental Program]	2
Laboratory Requirement	1
Total GIR Subjects Required for S.B. Degree	**17**

Plus
Departmental Program — **Units**

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

Required Subjects — **60**

18.03 Differential Equations, 12, REST; 18.02*
or
18.034 Differential Equations, 12, REST; 18.02*
18.310 Principles of Applied Mathematics, 12; 18.02*
18.311 Principles of Applied Mathematics, 12; 18.03*

One of the following two subjects:
18.04 Complex Variables with Applications, 12; 18.03*
18.112 Introduction to Functions of a Complex Variable, 12; 18.03*

One of the following two subjects:
18.06 Linear Algebra, 12, REST; 18.02*
18.421 Algorithmic Algebra and Number Theory, 12; 18.310*

Restricted Electives — **48**
Four additional Course 18 subjects from the following two groups with at least one subject from each group[1]

Group I - Probability and Statistics, Combinatorics, Computer Science
Group II - Numerical Analysis, Physical Mathematics, Fluid Mechanics

Departmental Program units that also satisfy the GIRs — **(12)**

Unrestricted Electives — **84**

Total Units Beyond the GIRs Required for S.B. Degree — **180**
No subject can be counted *both* as part of the 17-subject GIRs *and* as part of the 180 units required beyond the GIRs. *Every* subject in the student's departmental program will count toward one or the other, *but not both.*

Notes on Course XVIII
CLASS of 1996 or earlier: The Science Requirement is five subjects (since Biology is not required) but the REST Requirement is three subjects, keeping the total number of GIRs constant at 17. No more than one of the three REST subjects can be taken in the student's own department and at least one must be both taken outside the student's department *and* not used to satisfy the student's departmental program. Subjects designated as Science Distribution that were taken prior to fall 1993 will count toward fulfillment of the REST Requirement. See Chapter III for further details.

[1]A list of acceptable subjects is available in Room 2-108.

*Alternate prerequisites are listed in the subject description.

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Bachelor of Science in Mathematics/Course XVIII—Theoretical Mathematics Option
CLASS OF 1996 or earlier: See Notes on Course XVIII below.

General Institute Requirements (GIRs)	**Subjects**
Science Requirement	**6**
Humanities, Arts, and Social Sciences Requirement	**8**
Restricted Electives in Science and Technology (REST) Requirement [one subject can be satisfied by 18.03 or 18.034 in the Departmental Program]	**2**
Laboratory Requirement	**1**
Total GIR Subjects Required for S.B. Degree	**17**

Plus Departmental Program	**Units**
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics) **Required Subjects**	**72**

18.03 Differential Equations, 12, REST; 18.02*
or
18.034 Differential Equations, 12, REST; 18.02*
18.100B Analysis I, 12; 18.03*

One of the following two subjects:
18.101 Analysis II, 12; 18.100B, 18.700*
18.103 Fourier Analysis—Theory and Applications, 12; 18.100B
plus
18.701 Algebra I, 12
18.702 Algebra II, 12; 18.701
18.901 Introduction to Topology, 12; 18.100B

Restricted Electives	**36**
An upper-level Mathematics Seminar[1] (12 units)	
Two additional Course 18 subjects of essentially different content, with the first decimal digit one or higher (24 units)	
Departmental Program units that also satisfy the GIRs	**(12)**
Unrestricted Electives	**84**
Total Units Beyond the GIRs Required for S.B. Degree	**180**

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

Notes on Course XVIII
CLASS of 1996 or earlier: The Science Requirement is five subjects (since Biology is not required) but the REST Requirement is three subjects, keeping the total number of GIRs constant at 17. No more than one of the three REST subjects can be taken in the student's own department and at least one must be both taken outside the student's department *and* not used to satisfy the student's departmental program. Subjects designated as Science Distribution that were taken prior to fall 1993 will count toward fulfillment of the REST Requirement. See Chapter III for further details.

[1]These seminars are 18.104, 18.504, 18.704, 18.904, and 18.994.

*Alternate prerequisites are listed in the subject description.

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

Theoretical Mathematics Option

Theoretical mathematics (or "pure" mathematics) is the study of the basic concepts and structures that underlie the mathematical tools used in science and engineering. Its purpose is to search for 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 may also wish to explore such other topics as logic, number theory, complex analysis, geometry, and subjects within applied mathematics.

The subject 18.100B Analysis I is basic to the program. Since this subject is strongly proof-oriented, many students find an intermediate subject such as 18.06 Linear Algebra or 18.700 Linear Algebra useful as preparation.

The subject 18.701 Algebra I is more advanced and should not be elected until the student has had some experience with proofs (as in 18.100B or 18.700).

BACHELOR OF SCIENCE IN MATHEMATICS WITH COMPUTER SCIENCE, COURSE XVIII-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 the most 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 educate students in precisely these areas. First, the program provides a broad background in mathematics, equivalent to that of the other mathematics options, but emphasizing areas of greatest application to computer science.

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Bachelor of Science in Mathematics with Computer Science/Course XVIII–C
CLASS OF 1996 or earlier: See Notes on Course XVIII-C below.

General Institute Requirements (GIRs)	Subjects
Science Requirement	6
Humanities, Arts, and Social Sciences Requirement	8
Restricted Electives in Science and Technology (REST) Requirement [can be satisfied by 18.03 or 18.034 and 6.001 in the Departmental Program]	2
Laboratory Requirement	1
Total GIR Subjects Required for S.B. Degree	**17**

Plus
Departmental Program — **Units**

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

Required Subjects — **114 or 117**

18.03 Differential Equations, 12, REST; 18.02*
or
18.034 Differential Equations, 12, REST; 18.02*
18.310 Principles of Applied Mathematics, 12; 18.02*
18.404J Theory of Computation, 12; 18.310*
6.001 Structure and Interpretation of Computer Programs, REST; 15
6.034 Artificial Intelligence, 12; 6.001

One subject from each of the following pairs:
18.410J Introduction to Algorithms, 12; 6.001, 18.310*
or
18.414J Theory of Algorithms, 12; 18.06*, 18.310*
18.06 Linear Algebra, 12, REST; 18.02*
or
18.700 Linear Algebra, 12, REST; 18.02*
One of the following two sequences:
6.002 Circuits and Electronics, 15, REST; 8.02*, *18.03**
6.004 Computation Structures, 15; 6.001, 6.002
or
6.170 Laboratory in Software Engineering, 15; 6.001
6.035 Computer Language Engineering, 12; 6.170

Restricted Electives — **48**

Four additional Course 18 subjects, including subjects from at least three of the following areas: Algebra, Analysis, Logic, Probability, Numerical Analysis, and Combinatorics[1]

Departmental Program units that also satisfy the GIRs — **(27)**

Unrestricted Electives — **48-51**

Total Units Beyond the GIRs Required for S.B. Degree — **186**
No subject can be counted *both* as part of the 17-subject GIRs *and* as part of the 186 units required beyond the GIRs. *Every* subject in the student's departmental program will count toward one or the other, *but not both.*

Notes on Course XVIII-C
CLASS of 1996 or earlier: The Science Requirement is five subjects (since Biology is not required) but the REST Requirement is three subjects, keeping the total number of GIRs constant at 17. No more than one of the three REST subjects can be taken in the student's own department and at least one must be both taken outside the student's department *and* not used to satisfy the student's departmental program. Subjects designated as Science Distribution that were taken prior to fall 1993 will count toward fulfillment of the REST Requirement. See Chapter III for further details.

[1]A list of acceptable subjects is available in Room 2-108.

*Alternate prerequisites are listed in the subject description.

114
+ 48
162

Second, it provides a solid core of education in computer science, beginning with 6.001 Structure and Interpretation of Computer Programs, and 6.034 Artificial Intelligence. These are followed by either 6.002 Circuits and Electronics and 6.004 Computation Structures, which concentrate on the hardware aspects of computer science, or by 6.170 Laboratory in Software Engineering and 6.035 Computer Language Engineering, which concentrate on the software aspects. The program is completed with two advanced subjects, 18.404J Theory of Computation and 18.414J Theory of Algorithms, which provide an introduction to the most mathematically intensive branches of computer science.

Some flexibility is allowed in this program. For instance, students may, with permission, substitute 6.170 Laboratory in Software Engineering for the recommended subject 6.034 Artificial Intelligence, provided that they complete the 6.002-6.004 sequence and otherwise satisfy the Institute's Science Distribution Requirement. Similarly, students may, with permission, substitute 18.063 Introduction to Algebraic Systems for 18.310 Principles of Applied Mathematics, and 18.701 Algebra I for 18.06 Linear Algebra.

MINOR PROGRAM

The requirements for a **Minor in Mathematics** are as follows:

Six 12-unit subjects in mathematics, beyond the Institute calculus requirement, of essentially different content, including at least four advanced subjects (first decimal digit one or higher).

For a general description of the Minor Program, refer to Chapter III.

INQUIRIES

Inquiries regarding academic programs may be addressed to Joanne Jonsson, Undergraduate Mathematics Office, Room 2–108, MIT, Cambridge, MA 02139-4307, (617) 253–2416.

Additionally, the following information sheets are available in Room 2–108:
What Math Subject Shall I Take?
Careers in Mathematics
Thinking of Majoring in Mathematics?

Course 18

Mathematics

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For degree requirements, see listing in Chapter VII under the School of Science.

C

General Mathematics

18.01 Calculus

Prereq.: —
U (1, 2)
5-0-7 CALC I
Credit cannot also be received for 18.013, 18.014 or 18.01A

Differentiation and integration of functions of one variable, with applications. Concepts of function, limits, and continuity. Differentiation rules, application to graphing, rates, approximations, and extremum problems. Mean-value theorem. Definite and indefinite integration. Fundamental theorem of calculus. Applications of integration to geometry and science. Elementary functions. Techniques of integration. Approximation of definite integrals, improper integrals, and l'Hôpital's rule.
Term 1: *D. S. Jerison*

18.01A Calculus

(New)

Prereq.: One full year of high school calculus
U (1)
5-0-7 CALC I
Credit cannot also be received for 18.01, 18.013 or 18.014

Intended for students who have a had a full year of high school calculus. Covers the same material as 18.01. Taught in the first half of the Fall term.
Staff

18.013 Calculus with Applications

Prereq.: Assumes substantial prior knowledge of calculus
U (1)
5-0-7 CALC I
Credit cannot also be received for 18.01, 18.014 or 18.01A

Calculus of one variable, emphasizing applications. Quick review of differentiation (with optional tutorial sessions), followed by intensive study of integration and infinite series, including, as time permits, special topics selected from: perturbation and iteration procedures, stability, summation techniques, asymptotics, numerical analysis, and other techniques. Practice in mathematical formulation of scientific problems and approximate methods of solution.
Information: R. P. Stanley.

18.014 Calculus with Theory

Prereq.: —
U (1)
5-0-7 CALC I
Credit cannot also be received for 18.01, 18.013 or 18.01A

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

18.02 Calculus

Prereq.: 18.01 or 18.013 or 18.014
U (1, 2)
5-0-7 CALC II
Credit cannot also be received for 18.023, 18.024 or 18.02A

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, approximation techniques. Multiple integrals with applications. Vector fields, line and surface integrals, exact differentials, Green's theorem, Divergence Theorem, Stokes's Theorem. Additional topics: linear algebra (term 1).
Term 1: *H. Rogers*
Term 2: *Staff*

18.02A Calculus

(New)

Prereq.: 18.01A
U (1, IAP, 2)
5-0-7 CALC II
Credit cannot also be received for 18.02, 18.023 or 18.024

Covers material taught in the first half of 18.02 in the second six weeks of the Fall term. Second half of 18.02A can be taken either during IAP (daily lectures) or during the first half of the Spring term.
Staff

18.023 Calculus with Applications

Prereq.: 18.01 or 18.013
U (1, 2)
5-0-7 CALC II
Credit cannot also be received for 18.02, 18.024 or 18.02A

Calculus of several variables. Vector algebra, analytic geometry, planetary motion, orbit stability, partial differentiation, functions of several variables. Taylor series, extremal problems, numerical methods, multiple integrals, approximate and asymptotic methods of evaluation, applications, vector calculus, gradient, curl, theorems of Stokes, Green, and Gauss, conservation laws, fluid motion.
Term 1: *A. Toomre*
Term 2: *W. V. R. Malkus*

18.024 Calculus with Theory

Prereq.: 18.014
U (2)
5-0-7 CALC II
Credit cannot also be received for 18.02, 18.023 or 18.02A

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.
L. Hesselholt

18.03 Differential Equations

Prereq.: 18.02 or 18.023 or 18.014 *
U (1, 2, S)
4-0-8 REST
Credit cannot also be received for 18.034

Study of ordinary differential equations. Standard solution methods for one first-order equation, including graphical and numerical methods. Higher-order forced linear equations with constant coefficients. Complex numbers; Laplace transform. Matrix methods for first-order linear systems with constant coefficients. Non-linear systems; phase-plane analysis. Series solutions to second-order equations. Modeling of physical problems and interpretation of the analytic or graphical solutions.
Term 1: *G.-C. Rota*
Term 2: *A. P. Mattuck*

* Logic suggests 18.02A should be on this list. It is in 2007-08

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18.034 Differential Equations

Prereq.: 18.02 or 18.023 or 18.014
U (2)
4-0-8 REST
Credit cannot also be received for 18.03

Covers essentially the same material as 18.03 with more emphasis on theory. First order equations, separation, initial value problems. Systems, linear equations, independence of solutions, undetermined coefficients. Singular points and periodic orbits for planar systems.
R. B. Melrose

18.04 Complex Variables with Applications

Prereq.: 18.03 or 18.034
U (1, 2)
4-0-8
Credit cannot also be received for 18.075

Complex algebra and functions; analyticity; contour integration, Cauchy's theorem; singularities, Taylor and Laurent series; residues, evaluation of integrals; multivalued functions, potential theory in two dimensions; Fourier analysis and Laplace transforms.
Term 1: *H. Cheng*
Term 2: *A. Toomre*

18.05 Introduction to Probability and Statistics

Prereq.: 18.01 or 18.013 or 18.014
U (1, 2)
4-0-8 REST

Elementary introduction with applications. Basic probability models. Combinatorics. Random variables. Binomial, Poisson, geometric, exponential, and normal laws. Statistical estimation and testing. Confidence regions. Introduction to linear regression and analysis of variance.
Term 1: *S. Holmes*
Term 2: *R. M. Dudley*

18.06 Linear Algebra

Prereq.: 18.02 or 18.023 or 18.024
U (1, 2, S)
4-0-8 REST
Credit cannot also be received for 18.700

Basic subject on matrix theory and linear algebra, emphasizing topics useful in other disciplines, including systems of equations, vector spaces, determinants, eigenvalues, similarity, and positive definite matrices. Applications to Gauss elimination with pivoting, least-squares approximations, stability of differential equations, networks, linear programming, and Markov processes. Compared with 18.700, more emphasis on matrix algorithms and many applications.
Term 1: *H. R. Miller*
Term 2: *S. Lee*

18.062J Mathematics for Computer Science
(Revised Units)

(Same subject as 6.042J)
Prereq.: 18.02 or 18.023 or 18.024
U (1, 2)
5-0-7

See description under subject 6.042J.
C. E. Leiserson, F. T. Leighton, R. L. Rivest

18.063 Introduction to Algebraic Systems

Prereq.: 18.02 or 18.023 or 18.024, 18.062J/6.042J
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: U (2)
4-0-8

Introduction to algebraic systems, primarily for students interested in computer and information sciences, with emphasis on finite systems. Continuation of 18.062J/6.042J. Elementary number theory and group theory. Applications to fast arithmetic, cryptography, combinatorics. Elementary graph theory with applications to matching, circuits, planarity testing, and the four-color theorem. Introduction to rings and fields. Finite fields: coding theory, Hamming and BCH codes.
Information: M. X. Goemans.

18.075 Advanced Calculus for Engineers

Prereq.: 18.03 or 18.034
G (1, 2, S)
3-0-9 (H except II, VI, VIII, XII, XIII, XVI, XVIII, XXII)
Credit cannot also be received for 18.04

Functions of a complex variable; calculus of residues. Ordinary differential equations; integration by power series; Bessel and Legendre functions. Expansion in series of orthogonal functions, including Fourier series.
Y. Almog

18.076 Advanced Calculus for Engineers

Prereq.: 18.075
G (2, S)
3-0-9 (H except II, VI, XVI, XVIII, XXII)

Vector analysis: orthogonal curvilinear coordinates. Calculus of variations. Solution of classical partial differential equations of mathematical physics, including applications of conformal mapping and the Laplace transformation.
A. Toomre

18.085 Mathematical Methods for Engineers I

Prereq.: 18.03 or 18.034
G (1, 2, S)
3-0-9 H-LEVEL Grad Credit

Review of linear algebra, applications to networks, structures, and estimation, Lagrange multipliers, differential equations of equilibrium, Laplace's equation and potential flow, boundary-value problems, minimum principles and calculus of variations, Fourier series, discrete Fourier transform, convolution, applications.
Term 1: *Staff*
Term 2: *G. Strang*

18.086 Mathematical Methods for Engineers II

Prereq.: 18.03 or 18.034
G (1, 2, S)
3-0-9 H-LEVEL Grad Credit

Scientific computing: Fast Fourier Transform, finite differences, finite elements, spectral method, numerical linear algebra. Complex variables and applications. Initial-value problems: stability or chaos in ordinary differential equations, wave equation vs heat equation, conservation laws and shocks, dissipation and dispersion. Optimization: network flows, linear programming.
Information: G. Strang.

18.089 Review of Mathematics

Prereq.: —
G (S)
Units arranged

Reviews calculus and differential equations. Primarily for students in Course XIII-A. Degree credit allowed only in special circumstances.
Information: M. Artin.

18.093 Tutoring in Mathematics

Prereq.: 18.02 or 18.023 or 18.024
U (1, 2)
Units arranged [P/D/F]
Can be repeated for credit

For undergraduates who are teaching mathematics recitation. Limited enrollment, based on positions available. Permission must be secured in advance to register for this subject.
Information: M. Artin.

18.095 Mathematics Lecture Series

Prereq.: 18.01 or equivalent
U (IAP)
2-0-4 [P/D/F]
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: M. Artin.

18.098 Independent Activities

Prereq.: —
U (IAP)
Units arranged [P/D/F]
Can be repeated for credit

For undergraduates desiring credit for studies or for special individual reading on an undergraduate level on a P/D/F basis during IAP. Specific programs and credit arranged in consultation with individual faculty members and subject to departmental approval.
Information: M. Artin.

18.099 Independent Activities

Prereq.: —
U (1, IAP, 2)
Units arranged
Can be repeated for credit

For undergraduates desiring credit for studies during IAP or for special individual reading on an undergraduate level during the regular terms. Specific programs and credit arranged in consultation with individual faculty members and subject to departmental approval.
Information: M. Artin.

Analysis

18.100 Analysis I

Prereq.: 18.03 or 18.034
U (1, 2)
3-0-9 (H except XVIII)

Two options offered, both covering fundamentals of mathematical analysis: convergence of sequences and series, continuity, differentiability, Riemann integral, sequences and series of functions, uniformity, interchange of limit operations. Both options show the utility of abstract concepts and teach understanding and construction of proofs. *Option A*, offered first term only, chooses less abstract definitions and proofs, and gives applications where possible. *Option B* is more abstract and for students with more mathematical maturity. Places greater emphasis on point-set topology.
18.100A: *A. P. Mattuck*
18.100B: Information: R. B. Melrose.

18.101 Analysis II

Prereq.: 18.100; 18.700 or 18.701
U (1)
3-0-9 (H except XVIII)

Continues 18.100, in the direction of manifolds and global analysis. Differentiable maps, inverse and implicit function theorems, n-dimensional Riemann integral, change of variables in multiple integrals, manifolds, differential forms, n-dimensional version of Stokes' theorem. 18.901 helpful but not required.
S. Axelrod

18.103 Fourier Analysis — Theory and Applications

Prereq.: 18.100
U (2)
3-0-9 (H except XVIII)

Continues 18.100. Roughly half the subject devoted to the theory of the Lebesgue integral with applications to probability, and half to Fourier series and Fourier integrals.
V. W. Guillemin

18.104 Seminar in Analysis

Prereq.: 18.100
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: U (1)
3-0-9

Seminar for mathematics majors. Students present and discuss the subject matter, taken from current journals or books. Topics vary from year to year.
Information: R. B. Melrose.

18.112 Introduction to Functions of a Complex Variable

Prereq.: 18.03 or 18.034
U (2)
3-0-9 (H except XVIII)

A deeper and more extensive treatment of complex variables than 18.04, with more challenging problems. Mathematical rigor is, however, not stressed. Branch points and branch cuts. Cauchy's theorem, singularities, residues, contour integrals, conformal mapping. Schwarz-Christoffel transformation, analytic continuation, harmonic function, the Mittag-Leffler theorem.
A. Szenes

18.115 Functions of a Complex Variable

Prereq.: 18.100
G (1)
3-0-9 H-LEVEL Grad Credit

Exponential and trigonometric functions, Cauchy integral formula, holomorphic and meromorphic functions. Infinite series and products, the gamma function. Harmonic functions, conformal mapping, Dirichlet's problem.
S. Chang

18.116 Topics in Complex Variables

Prereq.: 18.115
Acad Year 1995-96: G (2)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics vary from year to year. Typical topics: introduction to Riemann Surface Theory, function-theoretic and geometric approaches to Teichmüller theory.
S. Chang

18.117 Topics in Several Complex Variables

Prereq.: 18.115, 18.125
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Pseudoconvex domains and plurisubharmonic functions. Existence and approximation theorems for holomorphic functions via L^2-estimates for the $\bar{\partial}$-operator.
Information: V. W. Guillemin.

18.125 Measure and Integration

Prereq.: 18.100
G (1)
3-0-9 H-LEVEL Grad Credit

Introduction to Lebesgue integration, with emphasis on applications to analysis on Euclidean space. Besides the standard theorems of abstract measure theory, surface measure and the divergence theorem are covered.
K. Liu

18.126 Functional Analysis

Prereq.: 18.125
G (2)
3-0-9 H-LEVEL Grad Credit

General theory of Hilbert and Banach spaces. Examples, including Sobolev spaces and L^p. The Fourier transform. Boundedness and compactness of operators. Spectral theory for self-adjoint operators. Applications to linear partial differential equations.
K. Liu

18.135 Geometric Analysis

Prereq.: 18.125
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit

Harmonic analysis on R^n. Radon transforms and applications. Spherical harmonics. Non-Euclidean Fourier analysis. Paley-Wiener type theorems, group-theoretic potential theory. Eigenfunctions, entire functionals, and hyper-functions.
Information: S. Helgason.

18.152 Introduction to Partial Differential Equations

Prereq.: 18.100
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: U (1)
3-0-9

Initial and boundary value problems for ordinary differential equations. Sturm-Liouville theory and eigenfunction expansions. Initial value problems for the wave equation and heat equation. The Dirichlet problem for Laplace's operator and potential theory.
Information: R. B. Melrose.

18.155 Distributions and Differential Equations

Prereq.: 18.103
G (2)
3-0-9 H-LEVEL Grad Credit

Distributions, Schwartz space, tempered distributions, convolutions and regularizations, Fourier transforms, Plancherel theorem, Payley-Wiener theorem; L^2 Sobolev spaces, Sobolev embedding theorems, L^2 elliptic regularity, compactness theorems; fundamental solutions, and second-order elliptic operators.
E. Meinrenken

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18.156 Introduction to Microlocal Analysis

Prereq.: 18.155, 18.965
G (1)
3-0-9 H-LEVEL Grad Credit

Examines singularities of distributions. Distributions singular across a submanifold, singular points of ordinary differential equations, non-characteristic boundary-value problems. Pseudodifferential operators, regularity of elliptic differential operators, wavefront set, and microdistributions. Darboux's theorem. Hamilton-Jacobi theory.
R. B. Melrose

18.157 Partial Differential Equations

Prereq.: 18.155, 18.156
G (2)
3-0-9 H-LEVEL Grad Credit

Analysis and geometry of linear and nonlinear elliptic operators. Basic facts from Riemannian geometry and elliptic partial differential equations; variational methods; real Monge-Ampère equations; global geometric problems associated with prescribing curvature.
R. B. Melrose

18.158 Topics in Differential Equations

Prereq.: 18.125
G (1)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year. Introduces a concept of natural functionals on solutions of a system of linear PDE and develops integral geometry from this point of view. Topics: elements of algebraic theory of D-modules. The Radon transform. Relation with representation theory. Integral geometry from the point of view of D-modules. Admissible families of curves and Einstein-Weyl 3-folds. Petrovsky theory of lacunas of hyperbolic equations. Prerequisities: generalized functions, elements of homological algebra.
R. B. Melrose

18.175 Theory of Probability

Prereq.: 18.125
G (2)
3-0-9 H-LEVEL Grad Credit

Ergodic theorems, laws of large numbers, convergence of probability measures, central limit theorems, stochastic processes, Brownian motion, martingales, strong Markov properties.
D. W. Stroock

18.177 Stochastic Processes

Prereq.: 18.175
G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

1995–96: An introduction to measurable dynamics and discrete interacting particle systems. First half of subject treats: recurrence, ergodicity, mixing, eigenvalues and eigenfunctions, Bernoulli processes, entropy, Ornstein's theorem, variational principle, and Gibbs measures in statistical mechanics. Second half of subject treats: coupling, correlation, duality, reversibility, stochastic Ising model, voter model, and exclusion process.
J. Propp

18.199 Graduate Analysis Seminar

Prereq.: Permission of instructor
G (1, 2)
3-0-21 H-LEVEL Grad Credit
Can be repeated for credit

Studies original papers in differential analysis and differential equations. Intended for first- and second-year graduate students. Permission must be secured in advance.
R. B. Melrose

18.238 Geometry and Quantum Field Theory

Prereq.: Permission of instructor
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year.
Information: I. M. Singer.

18.248 String Theory

Prereq.: Permission of instructor
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year.
Information: I. M. Singer.

18.276 Mathematical Methods in Physics

Prereq.: —
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year.
Information: V. Kač.

Applied Mathematics

18.303 Linear Partial Differential Equations

Prereq.: 18.03 or 18.034
U (2)
3-0-9

Introduces classical partial differential equations of applied mathematics: diffusion, Laplace/Poisson, and wave equations. Discussion of their origins and use in discrete random walks, heat conduction, potential theory, and waves of small amplitude arising in many areas of science and technology. Methods of solution emphasize separation of variables, Fourier series and transforms, Sturm-Liouville eigenvalue problems, and the cause-and-effect insights provided by Green's functions. 18.04 or 18.112 useful.
D. Z. Freedman

18.305 Methods of Applied Mathematics I

Prereq.: 18.04 or 18.075 or 18.112
G (1)
3-0-9 H-LEVEL Grad Credit

18.306 Methods of Applied Mathematics II

Prereq.: 18.04 or 18.075 or 18.112
G (2)
3-0-9 H-LEVEL Grad Credit

A comprehensive treatment of the advanced methods of applied mathematics. Term 1: asymptotic behavior of ordinary differential and difference equations; asymptotic evaluation of integrals; regular and singular perturbation methods; boundary-layer techniques; WKB method; multiple scales. Term 2: partial differential equations; transform methods; characteristics, initial and boundary-value problems; Green's functions; singular perturbation problems; nonlinear wave propagation.
18.305: *H. Cheng*
18.306: *R. R. Rosales*

18.307 Methods of Applied Mathematics III

Prereq.: 18.04 or 18.075 or 18.112
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit

Selection of material from the following topics: calculus of variations (the first variation and the second variation); integral equations (Volterra equations; Fredholm equations, the Hilbert-Schmidt theorem); the Hilbert Problem and singular integral equations of Cauchy type; Wiener-Hopf Method and partial differential equations; Wiener-Hopf Method and integral equations; group theory.
Information: H. Cheng.

18.308 Wave Motion

Prereq.: 18.305
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics selected according to interests of students and lecturer. Possible topics: 1) dispersive waves: modulation and average Lagrangian, group speed, wave action; 2) nonlinear geometrical optics: single and multiple phase waves, caustics, resonant interaction; 3) hyperbolic waves: characteristics, shocks, focusing, and reflection; 4) solitons, inverse scattering, complete integrability; 5) reacting gas dynamics: flames and detonations, acoustic interactions; 6) numerical methods for hyperbolic conservation laws.
Information: R. R. Rosales.

18.310 Principles of Applied Mathematics

Prereq.: 18.02 or 18.023 or 18.024
U (1)
3-0-9

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

18.311 Principles of Applied Mathematics

Prereq.: 18.03 or 18.034
U (2)
3-0-9

Introductory survey of fundamental concepts in applied mathematics: propagation, stability, equilibrium, optimization. This independent half of the complete sequence emphasizes the ideas and topics that relate to a "continuous" mathematical approach: diffusion, waves, instabilities, characteristics, and first-order partial differential equations, with applications to traffic problems, fluid flow, physics, and biology.
H. P. Greenspan

18.312 Algebraic Combinatorics

Prereq.: 18.702 or 18.703
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: U (1)
3-0-9

Applications of linear algebra and group theory to combinatorics. Topics include matching theory and extremal set theory, the matrix tree theorem, enumeration under group action, coverings and tilings, transfer matrices, and magic squares. No prior knowledge of combinatorics is assumed, though 18.314 is helpful.
Information: R. P. Stanley.

18.313 Probability

Prereq.: 18.02 or 18.023 or 18.024
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: U (2)
4-0-8
Credit cannot also be received for 18.440

Development of theory and applications of probabilistic concepts for scientists and engineers. Emphasizes formulation and solution of probabilistic problems by the algebra of random variables. Topics: sample space, Bernoulli and Poisson processes, uniform process, generating functions, discrete and continuous-parameter Markov chains. Introduces the Central Limit Theorem and the foundations of probability.
Information: G.-C. Rota.

18.314 Combinatorial Analysis

Prereq.: 18.02 or 18.023 or 18.024
U (2)
3-0-9

Combinatorial problems and methods for their solution. Enumeration, generating function techniques, and construction of bijections. Additional topics drawn from graph theory, matchings and network flows, partial orders, permutation groups and Polya theory. Prior experience with abstraction and proofs helpful.
S. Fomin

18.315 Combinatorial Theory

Prereq.: Permission of instructor
G (1)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year. Topic for 1995–96: Enumerative combinatorics.
R. P. Stanley

18.316 Seminar in Combinatorics

Prereq.: Permission of instructor
G (2)
3-0-9 H-LEVEL Grad Credit
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.
D. J. Kleitman

18.318 Topics in Combinatorics

Prereq.: Permission of instructor
G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year. Topics chosen from combinatorial methods, geometric combinatorics, and extremal problems.
D. J. Kleitman

18.325 Topics in Applied Mathematics

Prereq.: —
G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Selected topics in discrete and continuous applied mathematics. Topics vary from year to year.
G. Strang

18.330 Introduction to Numerical Analysis

Prereq.: 18.03 or 18.034
U (2)
3-0-9

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 Fortran, C, or Matlab helpful.
F. Waleffe

18.335 Numerical Methods of Applied Mathematics I

Prereq.: 18.03, 18.06, or equivalents
G (1)
3-0-9 H-LEVEL Grad Credit

18.336 Numerical Methods of Applied Mathematics II

Prereq.: 18.330, 18.335, or equivalents
G (2)
3-0-9 H-LEVEL Grad Credit

Advanced introduction to applications and theory of numerical methods. Term 1: IEEE standard, modern methods in iterative/dense numerical linear algebra, eigenvalues, Fast Fourier transforms, and multigrid including an application on a parallel computer. Term 2: Solution of differential equations, especially of time-dependent partial differential equations by finite difference and spectral methods. Well-posedness and stability. Fourier analysis. Boundary and nonlinear instabilities.
18.335: *A. Edelman*
18.336: *F. Waleffe*

18.337 Parallel Scientific Computing

Prereq.: 18.330, 18.335 or equivalents
G (2)
3-0-9 H-LEVEL Grad Credit

Advanced interdisciplinary introduction to modern scientific computing on parallel supercomputers. Numerical topics include dense and sparse linear algebra, N-body problems, and Fourier transforms. Geometrical topics include partitioning and mesh generation. Other topics include architectures and software systems with hands-on emphasis on understanding the realities and myths of what is possible on the world's fastest machines.
A. Edelman

MIT 1995

18.354 Fluid Mechanics

Prereq.: 18.04 or 18.075
U (1)
3-0-9 (H except XVIII)

Study of the basic concepts and laws of fluid motion as illustrated by a variety of readily observable phenomena and applications in science and technology: viscosity, vortices, waves, boundary layers, instability.
H. P. Greenspan

18.355 Fluid Mechanics

Prereq.: 18.354, 12.800, 2.25, 16.121 or equivalent
G (2)
3-0-9 H-LEVEL Grad Credit

Compact reviews of linear theories in fluid dynamics: boundary layers; instability; wave theory; and hydromagnetics. Foundations of non-linear studies in shear flow, convection, and vortex waves. Preparation for the more specialized fluids subjects 18.308, 18.356, and 18.358.
W. V. R. Malkus

18.356 Rotating Fluids

Prereq.: 18.305, 18.354
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit

General theory of rotating fluids; transient flows; boundary layers, nonlinear interactions; wave motion, stability theory. Application to technological and geophysical problems.
Information: W. V. R. Malkus.

18.357 Seminar in Fluid Dynamics

Prereq.: 18.354
G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Current developments in the theory and practice of the centrifugal separation of mixtures are discussed following a presentation of the relevant theory of rotating fluids. A seminar format with readings of published research complemented by laboratory demonstrations.
H. P. Greenspan

18.358 Hydrodynamic Stability and Turbulence

Prereq.: 18.354
Acad Year 1995-96: G (1)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit

Linear stability theory of incompressible and compressible flows. Nonlinear stability theory; modes of transition, the advent of aperiodicity. Upper-bound and statistical theories of turbulence. Statistical stability and the turbulent transport of heat and momentum. Properties of convection and shear turbulence.
W. V. R. Malkus

18.385 Nonlinear Dynamics and Chaos

Prereq.: 18.03 or 18.034
Acad Year 1995-96: G (1)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit

Introduces nonlinear dynamics with applications to physics, engineering, and biology, emphasizes analytical methods, examples, and geometric thinking. Topics: One- and two-dimensional flows and their bifurcations. Nonlinear oscillators. Chaos. Lorenz equations. Iterated maps. Period doubling and renormalization. Fractals.
R. R. Rosales

18.386 Advanced Nonlinear Dynamics and Chaos

Prereq.: 18.385 or a solid background in nonlinear dynamics
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit

Topics: chaos in forced oscillators; Hamiltonian chaos; 2-D maps; homoclinic tangles; Melnikov's method; strange attractors. Applications to biology and physics.
Information: R. P. Stanley.

18.395 Group Theory with Applications to Physics

Prereq.: 8.321
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit

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

18.396J Supersymmetric Quantum Field Theories
(Revised Content)

(Same subject as 8.896J)
Prereq.: 8.323
G (1)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics selected from the following: 1) SUSY algebras and their particle representations, 2) Weyl and Majorana spinors, 3) Lagrangians of basic 4-dimensional SUSY theories, both rigid SUSY and supergravity, 4) supermultiplets of fields and superspace methods, 5) renormalization properties, and the non-renormalization theorem, 6) spontaneous breakdown of SUSY, 7) phenomenological SUSY theories. Some prior knowledge of Noether's theorem, derivation and use of Feynman rules, l-loop renormalization, and gauge theories is essential.
D. Z. Freedman

Theoretical Computer Science

18.400J Automata, Computability, and Complexity

(Same subject as 6.045J)
Prereq.: 6.046J
U (2)
4-0-8

See description under subject 6.045J.
N. A. Lynch

18.404J Theory of Computation

(Same subject as 6.840J)
Prereq.: 18.310 or 18.063
G (1)
4-0-8 (H except XVIII)

A more extensive and theoretical treatment of the material in 6.045J/18.400J, emphasizing computability and computational complexity theory. Regular and context-free languages. Decidable and undecidable problems, reducibility, recursive function theory. Time and space measures on computation, completeness, hierarchy theorems, inherently complex problems, probabilistic computation, interactive proof systems.
M. Sipser

18.405J Advanced Complexity Theory

(Same subject as 6.841J)
Prereq.: 6.840J/18.404J
G (2)
3-0-9 H-LEVEL Grad Credit

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. Interactive proof systems and probabilistically checkable proofs. Approaches to the P = NP? and related questions.
M. Sipser

18.406 Concrete Complexity Theory

Prereq.: 18.404J/6.840J
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

A combinatorial treatment of complexity theory through concrete models of computation. Topics include communication complexity, decision trees, branching programs, algebraic computation, time-space tradeoffs, randomness as a resource, circuit complexity, etc.
Information: F. T. Leighton.

18.409 Topics in Theoretical Computer Science

Prereq.: Permission of instructor
G (1, 2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Study of an area of current interest in theoretical computer science. Topic varies from term to term. Topic for Term 1: Algorithmic aspects of computational molecular biology.
Term 1: *B. Berger*
Term 2: *Staff*

18.410J Introduction to Algorithms

(Same subject as 6.046J)
Prereq.: 6.001; 6.042J
U (1, 2)
4-0-8

See description under subject 6.046J.
Term 1: *C. E. Leiserson*
Term 2: *B. Berger*

18.414J Theory of Algorithms

(Same subject as 6.851J)
Prereq.: 18.06 or 18.700; 18.310 or 18.063
U (2)
3-0-9 (H except XVIII)

Techniques for design and analysis of algorithms, emphasizing mathematical methods and proofs. Proof-oriented version of 6.046J/18.410J. Topics: Data structures, sorting, selection, hashing. Solving recurrences. Upper and lower bounds. Dynamic programming. Divide and conquer. Graph algorithms: spanning trees, matching, shortest paths, max flow. Matrix operations. Fast Fourier transform. Integer and polynomial arithmetic. Permutation group membership. Primality testing. Linear programming. Parallel algorithms.
R. L. Rivest

18.415J Advanced Algorithms

(Same subject as 6.854J)
Prereq.: 18.410J/6.046J or 18.414J/6.851J; 18.06 or 18.700
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit

Continuation of 18.414J/6.851J, emphasizing fundamental algorithms and advanced methods of algorithmic design and analysis. Randomized algorithms. On-line algorithms. Interior point method for linear programming. Approximation algorithms. Basis reduction in lattices with applications.
Information: M. X. Goemans.

18.417 Introduction to Computational Molecular Biology

Prereq.: 6.001 or 18.410J/6.046J or permission of instructor
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit

Introduction to computational biology at the molecular level. Focuses on genomics and protein folding. Also includes computational approaches to: physical and genetic mapping, protein structure prediction, virus shell assembly, sequence homology and alignment, and evolutionary trees. No biology background is assumed.
Information: B. Berger.

18.419 Seminar in Theoretical Computer Science

Prereq.: Permission of instructor
G (1, 2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

A seminar on advanced topics in theoretical computer science. Current literature presented by students and instructors with a view toward preparing students for research in theoretical computer science, and for developing the skills needed to present such results effectively.
Term 1: *M. Sipser*
Term 2: *Staff*

18.421 Algorithmic Algebra and Number Theory

Prereq.: 18.310 or 18.063 or 18.701 or 18.703
U (2)
3-0-9

Review of basic concepts and methods of complexity theory. Existence and construction of efficient algorithms for classical problems in algebra, number theory, and logic. Integer and polynomial GCD computation, algebraic procedures in modular arithmetic, primality testing, factorization of polynomials over the rationals, structures and algorithms of recursion theory. Alternate years.
H. Rogers, Jr.

18.423J Computability, Logic, and Programming

(Same subject as 6.044J)
Prereq.: 18.063 or 18.310
U (1)
3-0-9

See description under subject 6.044J.
A. R. Meyer

18.425J Cryptography and Cryptanalysis

(Same subject as 6.875J)
Prereq.: 6.046J/18.410J or 6.851J/18.414J or 18.421
G (1)
3-0-9 H-LEVEL Grad Credit

See description under subject 6.875J.
S. Goldwasser

18.426J Advanced Topics in Cryptography

(Same subject as 6.876J)
Prereq.: Permission of instructor
Acad Year 1995-96: G (2)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

See description under subject 6.876J.
S. Micali

18.427J Program Semantics and Verification

(Same subject as 6.830J)
Prereq.: 6.821, 6.044J/18.423J or 6.045J/18.400J or 6.840J/18.404J
Acad Year 1995-96: G (2)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

See description under subject 6.830J.
A. R. Meyer

18.433 Combinatorial Optimization and Linear Programming

Prereq.: 18.06 or 18.700, 18.310
U (2)
3-0-9

A thorough treatment of linear programming theory, Dantzig's simplex method, and duality theory. Matroid optimization, the assignment problem, the maximum flow problem. Approximation algorithms for combinatorial optimization. Ellipsoid method and its implications for combinatorial optimization. Polyhedral approaches to NP-complete problems.
M. X. Goemans

18.435J Theory of Parallel and VLSI Computation

(Same subject as 6.848J)
Prereq.: 6.046J/18.410J or 6.851J/18.414J
G (1)
3-0-9 H-LEVEL Grad Credit

Introduces parallel computation and very large scale integration. Design and analysis of systolic algorithms for routing, sorting, arithmetic, and graph problems on arrays, trees, hypercubes, and other fixed-connection networks. Network transformations, broadcast simulation, retiming. Packet routing and nonblocking networks. Mathematical models of hardware. Lower bounds, P-completeness, area-time trade-offs. Layout, placement, routing. 3-D models, volume/area universal networks, fat-trees. Parallel programming on a connection machine. Survey of other parallel architectures.
F. T. Leighton

MIT 1995

18.436J Advanced Parallel and VLSI Computation

(Same subject as 6.849J)
Prereq.: 18.435J/6.848J
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit

Advanced topics in theory of parallel computation and very large scale integration. Parallel matching and related graph problems. Methods for removing randomness from algorithms. Automatic parallelization of straight-line code. AKS, columnsort, and universality. Packet routing. Fault tolerance. Network embedding problems. Network simulations. Current research topics. Alternate years.
Information: F. T. Leighton.

18.437J Distributed Algorithms

(Same subject as 6.852J)
Prereq.: 6.046J
Acad Year 1995-96: G (1)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit

See description under subject 6.852J.
N. A. Lynch

Applied Mathematics: Statistics

18.440 Probability and Random Variables

Prereq.: 18.02 or 18.023 or 18.024
U (1)
4-0-8
Credit cannot also be received for 18.313

Topics in applications. Probability spaces, random variables, distribution functions, expected value. Binomial, geometric, hypergeometric, Poisson distributions. Uniform, exponential, normal, gamma and beta distributions. Mean, variance, moments, and generating functions. Conditional probability, Bayes theorem, joint distributions, and distributions of transformed random variables. Tchebychev inequality, law of large numbers, and central limit theorem.
Term 1: *D. W. Stroock*
Term 2: *A. Sarkar*

18.441 Statistical Inference

Prereq.: 18.440 or 18.313 or 6.041
U (2)
3-0-9 (H except XVIII)

Reviews probability and introduces statistical inference. Point and interval estimation. The maximum likelihood method. Hypothesis testing. Likelihood-ratio tests and Bayesian methods. Nonparametric methods. Analysis of variance, regression analysis and correlation. Chi-square goodness of fit tests. More theoretical than 18.443 and more detailed in its treatment of statistics than 18.05.
S. Fomin

18.443 Statistics for Applications

Prereq.: 18.440 or 18.313 or 6.041
U (1)
3-0-9 (H except XVIII)

A broad treatment of statistics, concentrating on specific statistical techniques used in science and industry. Topics: hypothesis testing and estimation. Chi-square goodness of fit, regression, correlation, time-series analysis, analysis of variance and experimental design. Treatment more oriented toward application and less toward theory than 18.441.
S. Fomin

18.445 Introduction to Stochastic Processes

Prereq.: 18.313 or 18.440 or 6.041
G (2)
3-0-9 H-LEVEL Grad Credit

Introduces the theory and application of stochastic processes. Empirical phenomena for which stochastic processes provide models. Markov-chains. Markov processes. Renewal theory. Semi-Markov processes. Queueing theory and Brownian motion.
R. M. Dudley

18.446 Applied Time-Series Analysis

Prereq.: 15.075 or 18.441 or 18.443
G (2)
3-0-9 H-LEVEL Grad Credit

Statistical methods commonly used to analyze time series. Topics: Trends and seasonality. Autocorrelation and stationarity. Models for stationary series. ARIMA models. Model specification, parameter estimation, and model checking. Forecasting. Seasonal time series models. Intervention analysis and outlier detection. Fourier analysis and estimation of the spectrum. Cross-correlation and bivariate time series models. Multiple time series and vector ARIMA models.
A. Sarkar

18.454 Sampling, Simulation, and Monte Carlo

Prereq.: 18.440 or 18.313 or 6.041
G (1)
3-0-9 H-LEVEL Grad Credit

Introduction to principles and techniques of sampling for the purpose of a survey. Includes simple random sampling, stratified sampling, systematic sampling, and cluster sampling. Discussion of statistical background of Monte Carlo methods and simulation — prominent parts of experimental mathematics with wide applicability. Includes variance reduction, conditional Monte Carlo, control variates, antithetic variates, regression methods, Monte Carlo optimization, application to statistical inference problems.
A. Sarkar

18.455 Statistical Models
(Revised Content)

Prereq.: 18.06, 15.075 or 18.441 or 18.443
Acad Year 1995-96: G (1)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit

Statistical theory and method for scientific application. Techniques for experimental design, data analysis, estimation, inference, and prediction in statistical models. Linear and nonlinear regression analysis. Principal components. Analysis of variance and covariance. Model selection and diagnostics. Cross-validation. Numerical algorithms. Robust alternatives to least squares. Bootstrap and Monte Carlo methods for inference.
M. Matthews

18.456J Applied Multivariate Methods

(Same subject as 15.079J)
Prereq.: 18.06, 15.075 or 18.441 or 18.443
Acad Year 1995-96: G (2)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit

Theory and application of commonly used techniques involving multivariate data. Attention devoted to specific applications, and to computational facilities for applying the methods. Selects topics from the following: multivariate regression, discriminate analysis, and pattern classification. Cluster analysis, factor analysis, and principal components. Multidimensional scale analysis. Contingency tables.
M. Matthews

18.458 Robust Statistics and Nonparametric Methods

Prereq.: 15.075 or 18.441 or 18.443; 18.440
G (1)
3-0-9 H-LEVEL Grad Credit

Nonparametric methods that give useful and valid results under a very wide class of underlying distributions. Introduction to robust statistical theory. Topics: Wilcoxon test, sign test, Wilcoxon-Mann-Whitney test, U-statistics theorems. Asymptotic relative efficiency of estimators. Kruskal-Wallis test. Robus estimators of location.
M. Matthews

18.465 Topics in Statistics

Prereq.: Permission of instructor
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics selected from recent literature. Typical topics include nonparametric function estimation, statistical inverse theory, asymptotic theory for infinite-dimensional estimation problems.
Information: M. Matthews.

18.466 Mathematical Statistics

Prereq.: Permission of instructor
Acad Year 1995-96: G (1)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Decision theory, estimation, confidence intervals, hypothesis testing. Introduces large sample theory. Asymptotic efficiency of estimates. Exponential families. Sequential analysis.
R. M. Dudley

For additional related subjects in Statistics, see:

Civil and Environmental Engineering: 1.03, 1.151, 1.155, 1.202, 1.203J, 1.205, and 1.732

Electrical Engineering and Computer Science: 6.041, 6.231, 6.245, 6.262, 6.264J, 6.430J, 6.431, 6.432, and 6.435

Management: 15.034, 15.061, 15.065, 15.070, 15.074, 15.075, 15.076, 15.078, 15.098, 15.306, and 15.832

Mathematics: 18.05, 18.175, 18.177, 18.313, 18.440, 18.441, 18.443, 18.445, 18.446, 18.454, 18.455, 18.456J, 18.458, 18.465, and 18.466

See also: 2.061, 2.830, 2.870, 5.70, 5.72, 7.02, 8.044, 8.08, 10.816, 11.220, 11.221, 16.322, 17.842, 17.846, 22.38, HST 191, and MAS 622J.

Logic

18.504 Seminar in Logic

Prereq.: —
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: U (1)
3-0-9

Seminar for mathematics majors. Students present and discuss the subject matter taken from current journals or books. Topics vary from year to year.
Information: S. D. Friedman.

18.510 Introduction to Mathematical Logic and Set Theory

Prereq.: —
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: U (2)
3-0-9
Credit cannot also be received for 18.511

Zermelo-Fraenkel set theory. Ordinals and cardinals. Axiom of choice and transfinite induction. Propositional and predicate logic. Elementary model theory: completeness, compactness, and Lowenheim-Skolem theorems. Gödel incompleteness theorem. This subject introduces logic and set theory as a foundation for mathematics, and is especially recommended to students enrolled in theoretical mathematics subjects. 18.510 and 18.511 are offered in alternate years; they may not both be taken for credit.
Information: S. D. Friedman.

18.511 Introduction to Mathematical Logic and Recursion Theory

Prereq.: —
Acad Year 1995-96: U (2)
Acad Year 1996-97: **Not offered**
3-0-9
Credit cannot also be received for 18.510

Propositional and predicate logic. Elementary model theory: completeness, compactness, and Lowenheim-Skolem theorems. Elementary recursion theory: enumeration and recursion theorems. Post's Problem. Gödel incompleteness theorem. 18.511 and 18.510 are offered in alternate years; they may not both be taken for credit.
G. E. Sacks

18.515 Mathematical Logic

Prereq.: Permission of instructor
G (1)
3-0-9 H-LEVEL Grad Credit

First-order logic. Compactness and ultraproducts. Lowenheim-Skolem theorems and categoricity. Quantifier elimination. Recursively enumerable sets and definability in arithmetic. Incompleteness and undecidability.
S. D. Friedman

18.535 Graduate Logic Seminar

Prereq.: Permission of instructor
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Students report on fundamental papers in mathematical logic. Open to all graduate students with an interest in logic. Topics vary from year to year.
Information: S. D. Friedman.

18.575 Model Theory

Prereq.: Permission of instructor
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit

Topics in model theory chosen from stability theory, O-minimal structures, model-theoretic algebra, models of arithmetic.
Information: S. D. Friedman.

18.585 Set Theory

Prereq.: Permission of instructor
G (2)
3-0-9 H-LEVEL Grad Credit

Topics in set theory chosen from large cardinals, combinatorial set theory, forcing, descriptive set theory, fine structure theory. A previous subject in logic recommended but not required.
S. D. Friedman

Algebra and Number Theory

18.700 Linear Algebra

Prereq.: 18.02 or 18.023 or 18.024
U (1)
3-0-9 REST
Credit cannot also be received for 18.06

A rigorous treatment of linear algebra, including vector spaces, systems of linear equations, bases, linear independence, matrices, determinants, eigenvalues, inner products, quadratic forms, and canonical forms of matrices. Compared with 18.06, more emphasis on theory and proofs.
F. P. Peterson

18.701 Algebra I

Prereq.: —
U (1)
3-0-9

18.702 Algebra II

Prereq.: 18.701
U (2)
3-0-9

More extensive and theoretical than the 18.700–18.703 sequence. Experience with proofs helpful. First term: group theory, geometry, and linear algebra. Second term: rings and fields — ideals, polynomial rings, factorization, modules, Jordan form for matrices, extension fields, Galois theory.
M. Artin

18.703 Modern Algebra

Prereq.: 18.02 or 18.023 or 18.024
U (2)
3-0-9

A one-term treatment, covering the 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, 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. Kač

18.704 Seminar in Algebra and Number Theory

Prereq.: One subject in linear algebra and some experience with proofs
Acad Year 1995-96: U (1)
Acad Year 1996-97: **Not offered**
3-0-9

Seminar for mathematics majors. Students present and discuss the subject matter, taken from current journals or books. Topics may vary from year to year. Topic for 1995–96: Ideals, varieties, and algorithms.
S. Kleiman

18.705 Commutative Algebra

Prereq.: 18.701–18.702 or 18.700–18.703
G (1)
3-0-9 H-LEVEL Grad Credit

Basic topics in commutative algebra: localization, primary decomposition, integral dependence, filtrations, flatness, completions, and dimension theory.
K. Smith

18.706 Noncommutative Algebra

Prereq.: 18.705
G (2)
3-0-9 H-LEVEL Grad Credit

Wedderburn theory, Artinian algebras, tensor products, cohomology, central simple algebras, Jacobson density theorem, double centralizer theorem, Noether-Skolem theorem, Brauer groups, Galois cohomology, crossed product algebras, division algebras over local fields.
G. Lusztig

18.715 Topics in Homological Algebra

Prereq.: 18.705 or 18.905
Acad Year 1995-96: G (1)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics vary from year to year.
E. Getzler

18.725 Algebraic Geometry

Prereq.: 18.705
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit

Introduces the basic notions and techniques of modern algebraic geometry: schemes, maps, products, representable functors, and sheaf cohomology.
Information: S. Kleiman.

18.727 Topics in Algebraic Geometry

Prereq.: 18.725
Acad Year 1995-96: G (2)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics vary from year to year. Topic for 1995–96: Hodge theory.
T. Pantev

18.735 Topics in Algebra

Prereq.: 18.702 or 18.703
G (1)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics vary from year to year. Topic for 1995–96: Chiral algebras — a geometric approach to vertex operator algebras.
A. A. Beilinson

18.737 Quantum Groups

Prereq.: 18.705
G (1)
3-0-9 H-LEVEL Grad Credit

Main objective is the construction of semisimple groups and their generalization, the quantum groups, via the theory of quivers. No preliminaries in Lie groups or Lie algebras required. Good background in abstract algebra useful.
G. Lusztig

18.739 Theory of Invariants

Prereq.: 18.705
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit

Hilbert's finiteness theorem for reductive groups. Properties of the orbits and the orbit space. Classical invariants theory. Hilbert-Mumford-Richardson theorem. Rosenlicht's theorem on the existence of invariants. Matsushima criterion. Richardson's theorem on the principal stabilizer. Chevalley-Luna-Richardson theorem. Linear actions with a non-trivial stabilizer. Nice representations. Methods of the orbit classification. Applications to classical problems of linear algebra. Other topics.
Information: V. Kač.

18.745 Introduction to Lie Algebras

Prereq.: 18.701 or 18.703
G (1)
3-0-9 H-LEVEL Grad Credit

Emphasizes theory of Lie algebras and algebraic aspects of Lie theory. Structure of finite-dimensional Lie algebras; Engel and Lie theorems, Cartan subalgebras, Cartan criterion. Structure and classification of semisimple Lie algebras. Lie algebra cohomology; Weyl and Levi theorems. Finite-dimensional representations of semi-simple Lie algebras, Weyl character formula. Verma modules.
V. Kač

18.747 Infinite-dimensional Lie Algebras

Prereq.: 18.745
Acad Year 1995-96: G (2)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit

Topics vary from year to year. Representation theory of affine algebras and superalgebras and of superconformal algebras. Modular invariance and fusion rules. Vertex operator algebras.
V. Kač

18.755 Introduction to Lie Groups

Prereq.: 18.100, 18.700
G (1)
3-0-9 H-LEVEL Grad Credit

A general introduction to manifolds and Lie groups. The role of Lie groups in mathematics and physics. The exponential mapping. Correspondence with Lie algebras. Homogeneous spaces and transformation groups. Adjoint representation. Compact Lie groups. Structure theory and elementary representation theory.
D. A. Vogan

18.756 Analysis on Lie Groups

Prereq.: Elementary knowledge of Lie groups and manifold theory
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit

Semi-simple Lie groups and symmetric spaces. Topics in function theory on symmetric spaces, such as Fourier analysis and Radon transform, invariant differential operators, and potential theory. Emphasizes connections with classical analysis and representation theory.
Information: S. Helgason.

18.757 Representations of Lie Groups

Prereq.: 18.755
Acad Year 1995-96: G (2)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit

An introduction to representation theory of locally compact groups, with emphasis on compact groups and abelian groups. Peter-Weyl theorem and Cartan-Weyl highest weight theory for compact Lie groups.
S. Helgason

18.758 Representations of Lie Groups

Prereq.: 18.757
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit

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

18.769 Topics in Lie Theory

Prereq.: Permission of instructor
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Topics vary from year to year.
Information: D. A. Vogan.

M IT 1995

18.775 Algebraic Number Theory

Prereq.: 18.702
Acad Year 1995-96: G (1)
Acad Year 1996-97: **Not offered**
3-0-9 H-LEVEL Grad Credit

18.776 Algebraic Number Theory

Prereq.: 18.775
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (1)
3-0-9 H-LEVEL Grad Credit

18.775: The p-adic numbers. Number fields, rings of integers, valuations. Ramification, different and discriminant. Finiteness of ideal class groups. Zeta-function; units and Dirichlet theorem on regulators. Quadratic reciprocity law, cyclotomic fields and decomposition laws. Computation of class numbers of quadratic fields. 18.776: Division algebras and Brauer group. Local and global class field theory, including the cohomological approach and Lubin-Tate theory. Weil group. Tate's duality.
A. A. Beilinson

18.781 Theory of Numbers

Prereq.: 18.701 or 18.703
U (2)
3-0-9

Primes, congruences, quadratic reciprocity, and arithmetic functions. Diophantine equations, rational approximations, and continued fractions. Transcendence of e and π. Kronecker's theorem, the geometry of numbers. Quadratic forms and quadratic number fields. Euler's zeta function and its values at even integers.
S. Kleiman

18.785 Analytic Number Theory

Prereq.: 18.115
G (1)
3-0-9 H-LEVEL Grad Credit

Euler's zeta function and its properties. Distribution of prime numbers and Riemann's hypothesis. Zeta and L-functions of number fields, analysis on the group of adeles. Tamagawa measure. The p-adic version of Euler's zeta function. Chebotarev density theorem. The circle method of Hardy-Littlewood. Modular forms. Regulators and special values of zeta functions. Automorphic L-functions. Introduction to standard conjectures on L-functions.
R. B. Goncharov

18.786 Topics in Number Theory

Prereq.: Permission of instructor
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year.
Information: D. A. Vogan.

18.795 Multilinear Algebra

Prereq.: 18.700 or 18.701 or equivalent
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: G (2)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Intensive introduction to the basic concepts of multilinear algebra that are required for the further study of combinatorics, topology, algebraic topology, and Lie theory. Tensor algebras, exterior algebra, Clifford algebra, representations of the symmetric and general linear group, finer theory of Young symmetrizers, basic notions of Hopf algebra, introduction to supersymmetric algebra.
Information: G.-C. Rota.

Topology and Geometry

18.901 Introduction to Topology

Prereq.: 18.100
U (1, 2)
3-0-9 (H except XVIII)

Introduces topology, covering topics fundamental to modern analysis and geometry. Topological spaces, connectedness, compactness, continuous functions, separation axioms, function spaces. Metrization theorems, the Tychonoff theorem.
Term 1: *L. Hesselholt*
Term 2: *G. Lusztig*

18.904 Seminar in Topology

Prereq.: 18.901
U (2)
3-0-9

Seminar for mathematics majors. Students present and discuss the subject matter, taken from current journals or books. Topics may vary from year to year. Topics for 1995–96: fundamental group and covering spaces.
H. R. Miller

18.905 Algebraic Topology

Prereq.: 18.702 or 18.705; 18.901
G (1)
3-0-9 H-LEVEL Grad Credit

18.906 Algebraic Topology

Prereq.: 18.905
G (2)
3-0-9 H-LEVEL Grad Credit

Simplicial and singular homology, Eilenberg-Steenrod axioms. Cohomology ring, universal coefficient theorem, Künneth theorem, plus additional toipcs to be chosen by the instructor (such as homotopy theory, duality in manifolds).
F. P. Peterson

18.915 Graduate Topology Seminar

Prereq.: 18.906
G (1)
3-0-21 H-LEVEL Grad Credit

Study and discussion of important original papers in the various parts of algebraic and differential topology. Open to all students who have had 18.906 or the equivalent, not only prospective topologists.
D. M. Kan

18.917 Topics in Algebraic Topology

Prereq.: 18.906
G (1)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year. Topics may include: cohomology operations, homotopy theory, K-theory, cobordism theory, stable homotopy theory, localization, mapping spaces.
M. J. Hopkins

18.950 Differential Geometry

Prereq.: 18.100, *18.901*
U (2)
3-0-9

An introduction to differential geometry, with emphasis on curves and surfaces. Frenet formulas, fundamental forms, curvature, Gauss' theorem, geodesics, Riemannian manifolds. 18.901 is required, but may be taken concurrently.
S. Axelrod

18.965 Geometry of Manifolds

Prereq.: 18.101
G (1)
3-0-9 H-LEVEL Grad Credit

18.966 Geometry of Manifolds

Prereq.: 18.965
G (2)
3-0-9 H-LEVEL Grad Credit

Differentiable manifolds, vector fields and forms, introduction to Lie groups, the DeRham theorem, Riemannian manifolds. 18.966 continues 18.965. Focuses on global differential geometry, heat kernels, and index theorems.
V. W. Guillemin

18.969 Topics in Geometry

Prereq.: 18.965
G (1)
3-0-9 H-LEVEL Grad Credit
Can be repeated for credit

Content varies from year to year.
Information: R. B. Melrose.

18.994 Seminar in Geometry

Prereq.: —
Acad Year 1995-96: **Not offered**
Acad Year 1996-97: U (2)
3-0-9

Seminar for mathematics majors. Students present and discuss the subject matter, taken from current journals or books. Topics may vary from year to year.
Information: R. B. Melrose.

18.999 Mathematical Reading

Prereq.: —
G (1, 2, S)
Units arranged
Can be repeated for credit

Reading of advanced mathematical treatises under supervision of a member of the Department. For graduate students desiring advanced work not provided in regular subjects.
D. A. Vogan

18 UR Undergraduate Research

Prereq.: —
U (1, 2)
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: M. Artin.

18 ThG Graduate Thesis

Prereq.: —
G (1, 2)
Units arranged H-LEVEL Grad Credit
Can be repeated for credit

Program of graduate research, leading to the writing of a Ph.D. thesis; to be arranged by the student and an appropriate MIT faculty member.