MATHEMATICS

Emeriti: (Professors) Kai Lai Chung, Solomon Feferman, Robert Finn, Samuel Karlin, Joseph Keller, Georg Kreisel, Harold Levine, R. James Milgram, Donald Ornstein, Robert Osserman

Chair: Rafe Mazzeo

Professors: Gregory Brumfiel, Daniel Bump, Gunnar Carlsson, Ralph L. Cohen, Amir Dembo, Persi Diaconis, Yakov Eliashberg, Eleny Ionel, Yitzhak Katznelson, Steven Kerckhoff, Jun Li, Tai-Ping Liu, Rafe Mazzeo, George Papanicolaou, Richard Schoen, Leon Simon, Kannan Soundararajan, Ravi Vakil, Brian White

Associate Professor: Andras Vasy

Assistant Professors: Simon Brendle, Soren Galatius

Szegö Assistant Professors: Laurent Demanet, Larry Guth, Gautam Iyer, Joan Licata, Todor Milanov, Dragos Oprea, Alexandra Pettet, Antoine Toussaint, Denis Trotabas, Leo Tzou

Lecturers: Andrew Blumberg, Christopher Douglas, Victor Eliashberg, Benjamin Lee, Mark Lucianovic, Laurence Nedelec, James Nolen, Richard Siefring, Wojciech Wieczorek

Acting Assistant Professor: Samuel Payne

Courtesy Professors: Renata Kallosh, Grigori Mints

Consulting Professors: Brian Conrey, Keith Devlin, David Hoffman, Wu-chung Hsiang

Visiting Professor: Helmut Hofer

Samelson Fellows: Anthony Licata, Samuel Lisi, Matthew Kahle

Web site: http://math.stanford.edu

Courses given in Mathematics have the subject code MATH. For a complete list of subject codes, see Appendix.

The Department of Mathematics offers programs leading to the degrees of Bachelor of Science, Master of Science, and Doctor of Philosophy in Mathematics, and participates in the program leading to the B.S. in Mathematical and Computational Science. The department also participates in the M.S. and Ph.D. degree programs in Scientific Computing and Computational Mathematics and the M.S. degree program in Financial Mathematics.

ADVANCED PLACEMENT FOR FRESHMEN

Students of unusual ability in mathematics often take one or more semesters of college-equivalent courses in mathematics while they are still in high school. Under certain circumstances, it is possible for such students to secure both advanced placement and credit toward the bachelor's degree. A decision as to placement and credit is made by the department after consideration of the student's performance on the Advanced Placement Examination in Mathematics (forms AB or BC) of the College Entrance Examination Board, and also after consideration of transfer credit in mathematics from other colleges and universities.

The department does not give its own advanced placement examination. Students can receive either 5 or 10 units of advanced placement credit, depending on their scores on the CEEB Advanced Placement Examination. Entering students who have credit for two quarters of single variable calculus (10 units) are encouraged to enroll in MATH 51-53 in multivariable mathematics, or the honors version 51H-53H. These three-course sequences, which can be completed during the freshman year, supply the necessary mathematics background for most majors in science and engineering. They also serve as excellent background for the major or minor in Mathematics, or in Mathematical and Computational Science. Students who have credit for one quarter of single variable calculus (5 units) should take MATH 42 in the Autumn Quarter and 51 in Winter Quarter. Options available in the Spring Quarter include MATH 52, 53, or 103. For proper placement, contact the Department of Mathematics.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

The following department requirements are in addition to the University's basic requirements for the bachelor's degree:

MAJOR

Students wishing to major in Mathematics must satisfy the following requirements:

1. Department of Mathematics courses (other than MATH 100) totaling at least 49 units credit; such courses must be taken for a letter grade. For the purposes of this requirement, STATS 116, PHIL 151, and PHIL 152 count as Department of Mathematics courses.
2. Additional courses taken from Department of Mathematics courses numbered 101 and above or from approved courses in other disciplines with significant mathematical content, totaling at least 15 units credit. At least 9 of these units must be taken for a letter grade.
3. A Department of Mathematics adviser must be selected, and the courses selected under items '1' and '2' above must be approved by the department's director of undergraduate study, acting under guidelines laid down by the department's Committee for Undergraduate Affairs. The Department of Mathematics adviser can be any member of the department's faculty.
4. To receive the department's recommendation for graduation, a student must have been enrolled as a major in the Department of Mathematics for a minimum of two full quarters, including the quarter immediately before graduation. In any case, students are strongly encouraged to declare as early as possible, preferably by the end of the sophomore year.

Students are normally expected to complete either the sequence 19, 20, 21 or the sequence 41, 42 (but not both). Students with an Advanced Placement score of at least 4 in BC math or 5 in AB math may receive 10 units credit and fulfill requirement '1' by taking at least 39 units of Department of Mathematics courses numbered 51 and above. Students with an Advanced Placement score of at least 3 in BC math or at least 4 in AB math may receive 5 units credit and fulfill requirement '1' by taking at least 44 units of Department of Mathematics courses numbered 42 and above.

Sophomore seminar courses may be counted among the choice of courses under item '1'. Other variations of the course requirements laid down above (under items '1' and '2') may, in some circumstances, be allowed. For example, students transferring from other universities may be allowed credit for some courses completed before their arrival at Stanford. However, at least 24 units of the 49 units under item '1' above and 9 of the units under item '2' above must be taken at Stanford. In all cases, approval for variations in the degree requirements must be obtained from the department's Committee for Undergraduate Affairs. Application for such approval should be made through the department's director of undergraduate study.

It is to be emphasized that the above regulations are minimum requirements for the major; students contemplating graduate work in mathematics are strongly encouraged to include the courses 116, 120, 121, 147 or 148, and 171 in their selection of courses, and in addition, take at least three Department of Mathematics courses over and above the minimum requirements laid out under items '1' and '2' above, including at least one 200-level course. Such students are also encouraged to consider the possibility of taking the honors program, discussed below.

To help develop a sense of the type of course selection (under items '1' and '2' above) that would be recommended for math majors with various backgrounds and interests, see the following examples. These represent only a few of a very large number of possible combinations of courses that could be taken in fulfillment of the Mathematics major requirements:

Example 1—A general program (a balanced program of both pure and applied components, without any particular emphasis on any one field of mathematics or applications) as follows:

a) either MATH 19, 20, and 21, or 41 and 42 (or satisfactory Advanced Placement credit); 51, 52, 53; 103; 106; 109; 110; 111; 115

Mathematics

b) plus any selection of at least eight of the following courses, including three Department of Mathematics courses: MATH 108, 131, 132, 143, 146, 147, 148, 152, 161; CS 137; ECON 50; PHYSICS 41, 43, 45; STATS 115. These courses from other departments are only meant as examples; there are many suitable courses in several departments that can be taken to fulfill part or all of requirement '2.'

Example 2—A theoretical program recommended for those contemplating possible later graduate work providing an introduction to the main areas of mathematics both broader and deeper than the general program outlined above; see, also, the discussion of the honors program below:

a) either MATH 19, 20 and 21, or 41 and 42 (or satisfactory Advanced Placement credit)
b) either the sequence 51, 52, 53, or the sequence 51H, 52H, 53H; 106 or 116; 113; 120; 171
c) plus nine or more of the following courses, including at least one from each group: algebra sequence 114, 121, 152, 156; analysis sequence 131, 132, 135, 151, 174A,B, 175; geometry/topology sequence 143, 145, 146, 147, 148; logic and set theory sequence PHIL 151, 152; MATH 161.

In addition, those contemplating eventual graduate work in Mathematics should consider including at least one graduate-level math course such as MATH 205A, 210A, or 215A or B. Such students should also consider the possibility of entering the honors program.

*Example 3**—An applied mathematics program:

a) either MATH 19, 20, and 21; or 41 and 42 (or satisfactory Advanced Placement credit); 51, 52, 53; 103; 106; 108; 109; 110; 111; 115; 131; STATS 116
b) plus at least 15 units of additional courses in Applied Mathematics, including, for example, suitable courses from the departments of Physics, Computer Science, Economics, Engineering, and Statistics.

* Students with interests in applied mathematics, but desiring a broader-based program than the type of program suggested in Example 3, including significant computational and/or financial and/or statistical components, are encouraged to also consider the Mathematics and Computational Science program.

MINOR

To qualify for the minor in Mathematics, a student should complete, for a letter grade, at least six Department of Mathematics courses (other than MATH 100) numbered 51 or higher, totaling a minimum of 24 units. It is recommended that these courses include either the sequence 51, 52, 53 or the sequence 51H, 52H, 53H. At least 12 of the units applied toward the minor in Mathematics must be taken at Stanford. The policy of the Mathematics Department is that no courses other than the MATH 50 series and below may be double-counted toward any other University major or minor.

HONORS PROGRAM

The honors program is intended for students who have strong theoretical interests and abilities in mathematics. The goal of the program is to give students a thorough introduction to the main branches of mathematics, especially analysis, algebra, and geometry. Through the honors thesis, students may be introduced to a current or recent research topic, although occasionally more classical projects are encouraged. The program provides an excellent background with which to enter a master's or Ph.D. program in Mathematics. Students completing the program are awarded a B.S. in Mathematics with Honors.

It is recommended that the sequence 51H, 52H, 53H be taken in the freshman year. Students who have instead taken the sequence 51, 52, 53 in their freshman year may be permitted to enter the honors program, but such entry must be approved by the Department of Mathematics Committee for Undergraduate Affairs.

To graduate with a B.S. in Mathematics with Honors, the following conditions apply in addition to the usual requirements for math majors:

1. The selection of courses under items '1' and '2' above must include all the math courses 106 or 116, 120, 171 and also must include seven or more additional courses, with at least one from each of the groups: algebra sequence 114, 121, 152, 153, 156; analysis sequence 131, 132, 135, 136, 151, 174A, 174B, 175, 176; geometry/topology sequence 143, 145, 146, 147, 148; logic and set theory sequence PHIL 151, PHIL 152, and MATH 161.
2. Students in the honors program must write a senior thesis. In order to facilitate this, the student must, by the end of the junior year, choose an undergraduate thesis adviser from the Department of Mathematics faculty, and map out a concentrated reading program under the direction and guidance of the adviser. During the senior year, the student must enroll in MATH 197 for a total of 6 units (typically spread over two quarters), and work toward completion of the thesis under the direction and guidance of the thesis adviser. The thesis may contain original material, or be a synthesis of work in current or recent research literature. The 6 units of credit for MATH 197 are required in addition to the course requirements laid out under items '1' and '2' above and in addition to all other requirements for math majors.

In addition to the minimum requirements laid out above, it is strongly recommended that students take at least one graduate-level course (that is, at least one course in the 200 plus range). MATH 205A, 210A, and 215A or B are especially recommended in this context.

Students with questions about the honors program should see the director of undergraduate advising.

BACHELOR OF SCIENCE IN MATHEMATICAL AND COMPUTATIONAL SCIENCE

The Department of Mathematics participates with the departments of Computer Science, Management Science and Engineering, and Statistics in a program leading to a B.S. in Mathematical and Computational Science. See the "Mathematical and Computational Science" section of this bulletin.

GRADUATE PROGRAMS

MASTER OF SCIENCE

The University's basic requirements for the master's degree are discussed in the "Graduate Degrees" section of this bulletin. Students should pay particular attention to the University's course requirements for graduate degrees. The following are specific departmental requirements:

Candidates must complete an approved course program of 45 units of courses beyond the department requirements for the B.S. degree, of which at least 36 units must be Mathematics Department courses, taken for a letter grade. The Mathematics courses must include at least 18 units numbered 200 or above. The candidate must have a grade point average (GPA) of 3.0 (B) over all course work taken in Mathematics, and a GPA of 3.0 (B) in the 200-level courses considered separately. Course work for the M.S. degree must be approved during the first quarter of enrollment in the program by the department's Director of Graduate Studies.

For the M.S. degree in Financial Mathematics, see the "Financial Mathematics" section of this bulletin.

TEACHING CREDENTIALS

For information concerning the requirements for teaching credentials, see the "School of Education" section of this bulletin or address inquiries to Credential Secretary, School of Education.

DOCTOR OF PHILOSOPHY

The University's basic requirements for the doctorate (residence, dissertation, examinations, etc.) are discussed in the "Graduate Degrees" section of this bulletin. The following are specific departmental requirements.

To be admitted to candidacy, the student must have successfully completed 27 units of graduate courses (that is, courses numbered 200 and above). In addition, the student must pass qualifying examinations given by the department.

Beyond the requirements for candidacy, the student must complete a course of study approved by the Graduate Affairs Committee of the Department of Mathematics and submit an acceptable dissertation. In accordance with University requirements, Ph.D. students must complete a total of 135 course units beyond the bachelor's degree. These courses should be Department of Mathematics courses or approved courses from other departments. The course program should display substantial breadth in mathematics outside the student's field of application. The student must receive a grade point average (GPA) of 3.0 (B) or better in courses used to satisfy the Ph.D. requirement. In addition, the student must pass the Department area examination and the University oral examination and pass a reading examination in one foreign language, chosen from French, German, or Russian.

Experience in teaching is emphasized in the Ph.D. program. Each student is required to complete nine quarters of such experience. The nature of the teaching assignment for each of those quarters is determined by the department in consultation with the student. Typical assignments include teaching or assisting in teaching an undergraduate course or lecturing in an advanced seminar.

For further information concerning degree programs, fellowships, and assistantships, inquire of the academic associate of the department.

PH.D. MINOR

The student should complete both of the following:*

1. MATH 106 or 116, 131, 132
2. MATH 113, 114, 120 or 152

These courses may have been completed during undergraduate study, and their equivalents from other universities are acceptable.

In addition, the student should complete 21 units of 200-level courses in Mathematics. These must be taken at Stanford and approved by the Department of Mathematics Ph.D. minor adviser.

* A third coherent sequence designed by the student, subject to the approval of the graduate committee, may be considered as a substitute for items '1' or '2'.

COURSES

WIM indicates that the course satisfies the Writing in the Major requirements.

INTRODUCTORY AND UNDERGRADUATE

The department offers two sequences of introductory courses in single variable calculus.

1. MATH 41, 42 present single variable calculus. Differential calculus is covered in the first quarter, integral calculus in the second.
2. MATH 19, 20, 21 cover the material in 41, 42 in three quarters instead of two.

There are options for studying multivariable mathematics:

1. MATH 51, 52, 53 cover differential and integral calculus in several variables, linear algebra, and ordinary differential equations. These topics are taught in an integrated fashion and emphasize application. MATH 51 covers differential calculus in several variables and introduces matrix theory and linear algebra, 52 covers integral calculus in several variables and vector analysis, 53 studies further topics in linear algebra and applies them to the study of ordinary differential equations. This sequence is strongly recommended for incoming freshmen with 10 units of advanced placement credit.
2. MATH 51H, 52H, 53H cover the same material as 51, 52, 53, but with more emphasis on theory and rigor.

The introductory course in linear algebra is 103 or 113. There are no formal prerequisites for these courses, but appropriate mathematical maturity is expected. Much of the material in 103 is covered in the sequence 51, 52, 53.

MATH 15. Overview of Mathematics—Broad survey of mathematics; its nature and role in society. GER:DB-Math
3 units, Win (Devlin, K)

MATH 19. Calculus—The content of MATH 19, 20, 21 is the same as the sequence MATH 41, 42 described below, but covered in three quarters, rather than two. GER:DB-Math
3 units, Aut (Lee, B), Win, Sum (Staff)

MATH 20. Calculus—Continuation of 19. Prerequisite: 19. GER:DB-Math
3 units, Win (Lee, B), Spr (Staff)

MATH 21. Calculus—Continuation of 20. Prerequisite: 20. GER:DB-Math
4 units, Spr (Lee, B)

MATH 41. Calculus—Introduction to differential and integral calculus of functions of one variable. Topics: review of elementary functions including exponentials and logarithms, rates of change, and the derivative. Introduction to the definite integral and integration. Prerequisites: algebra, trigonometry. GER:DB-Math
5 units, Aut (Lucianovic, M)

MATH 41A. Calculus ACE—Students attend MATH 41 lectures with different recitation sessions, four hours instead of two, emphasizing engineering applications. Prerequisite: application; see http://soe.stanford.edu/edp/programs/ace.html. GER:DB-Math
6 units, Aut (Lucianovic, M)

MATH 42. Calculus—Continuation of 41. Methods of symbolic and numerical integration, applications of the definite integral, introduction to differential equations. Infinite series. Prerequisite: 41 or equivalent. GER:DB-Math
5 units, Aut, Win (Butscher, A)

MATH 42A. Calculus ACE—Students attend MATH 41 lectures with different recitation sessions, four hours instead of two, emphasizing engineering applications. Prerequisite: application; see http://soe.stanford.edu/edp/programs/ace.html. GER:DB-Math
6 units, Aut, Win (Butscher, A)

MATH 51. Linear Algebra and Differential Calculus of Several Variables—Geometry and algebra of vectors, systems of linear equations, matrices, vector valued functions and functions of several variables, partial derivatives, gradients, chain rule in several variables, vector fields, optimization. Prerequisite: 21, 42, or a score of 4 on the BC Advanced Placement exam or 5 on the AB Advanced Placement exam, or consent of instructor. GER:DB-Math
5 units, Aut, Win, Spr, Sum (Staff)

MATH 51A. Linear Algebra and Differential Calculus of Several Variables, ACE—Students attend MATH 51 lectures with different recitation sessions: four hours per week instead of two, emphasizing engineering applications. Prerequisite: application; see http://soe.stanford.edu/edp/programs/ace.html. GER:DB-Math
6 units, Aut, Win, Spr (Staff)

MATH 51H. Honors Multivariable Mathematics—For prospective Mathematics majors in the honors program and students from other areas of science or engineering who have a strong mathematics background. Three quarter sequence covers the material of 51, 52, 53, and additional advanced calculus and ordinary and partial differential equations. Unified treatment of multivariable calculus, linear algebra, and differential equations with a different order of topics and emphasis from standard courses. Students should know one-variable calculus and have an interest in a theoretical approach to the subject. Prerequisite: score of 5 on BC Advanced Placement exam, or consent of instructor. GER:DB-Math
5 units, Aut (Simon, L)

MATH 52. Integral Calculus of Several Variables—Iterated integrals, line and surface integrals, vector analysis with applications to vector potentials and conservative vector fields, physical interpretations. Divergence theorem and the theorems of Green, Gauss, and Stokes. Prerequisite: 51. GER:DB-Math
5 units, Aut (Oprea, D), Win (Demanet, L; Lucianovic, M), Spr (Butscher, A)

MATH 52H. Honors Multivariable Mathematics—Continuation of 51H. Prerequisite: 51H. GER:DB-Math
5 units, Win (Simon, L)

MATH 53. Ordinary Differential Equations with Linear Algebra—Linear ordinary differential equations, applications to oscillations, matrix methods including determinants, eigenvalues and eigenvectors, matrix exponentials, systems of linear differential equations with constant coefficients, stability of non-linear systems and phase plane analysis, numerical methods, Laplace transforms. Integrated with topics from linear algebra (103). Prerequisite: 51. GER:DB-Math

5 units, Aut (Staff), Win (Liu, T), Spr (Guth, L; Siefring, R), Sum (Staff)

MATH 53H. Honors Multivariable Mathematics—Continuation of 52H. Prerequisite: 52H. GER:DB-Math

5 units, Spr (Brendle, S)

MATH 80Q. Capillary Surfaces: Explored and Unexplored Territory—Stanford Introductory Seminar. Preference to sophomores. Capillary surfaces: the interfaces between fluids that are adjacent to each other and do not mix. Recently discovered phenomena, predicted mathematically and subsequently confirmed by experiments, some done in space shuttles. Interested students may participate in ongoing investigations with affinity between mathematics and physics.

3 units, Win (Finn, R)

MATH 87Q. Mathematics of Knots, Braids, Links, and Tangles—Stanford Introductory Seminar. Preference to sophomores. Types of knots and how knots can be distinguished from one another by means of numerical or polynomial invariants. The geometry and algebra of braids, including their relationships to knots. Topology of surfaces. Brief summary of applications to biology, chemistry, and physics.

3 units, Spr (Wieczorek, W)

UNDERGRADUATE AND GRADUATE

Unless stated, there are no prerequisites for the courses listed below. Where a prerequisite is stated, it may be waived by the instructor.

MATH 100. Mathematics for Elementary School Teachers—Mathematics and pedagogical strategies. Core mathematical content in grades K-6, classroom presentation, how to handle student errors, and mathematical issues that come up during instruction.

4 units, Spr (Milgram, R)

MATH 103. Matrix Theory and Its Applications—Linear algebra and matrices, emphasizing the computational and algorithmic aspects and the scientific problems in which matrix theory is applied. Solution of linear equations. Linear spaces and matrices. Orthogonal projection and least squares. Determinants, eigenvalues, and eigenvectors. GER:DB-Math

3 units, Aut (Milanov, T), Win, Spr (Nedelec, L), Sum (Staff)

MATH 106. Functions of a Complex Variable—Complex numbers, analytic functions, Cauchy-Riemann equations, complex integration, Cauchy integral formula, residues, elementary conformal mappings. Prerequisite: 52. GER:DB-Math

3 units, Win (Licata, J), Sum (Brumfiel, G)

MATH 108. Introduction to Combinatorics and Its Applications—Topics: graphs, trees (Cayley's Theorem, application to phylogony), eigenvalues, basic enumeration (permutations, Stirling and Bell numbers), recurrences, generating functions, basic asymptotics. Prerequisites: 51 or 103 or equivalent. GER:DB-Math

3 units, Spr (Diaconis, P)

MATH 109. Applied Group Theory—Applications of the theory of groups. Topics: elements of group theory, groups of symmetries, matrix groups, group actions, and applications to combinatorics and computing. Applications: rotational symmetry groups, the study of the Platonic solids, crystallographic groups and their applications in chemistry and physics. GER:DB-Math, WIM

3 units, Aut (Ionel, E)

MATH 110. Applied Number Theory and Field Theory—Number theory and its applications to modern cryptography. Topics: congruences, finite fields, primality testing and factorization, public key cryptography, error correcting codes, and elliptic curves, emphasizing algorithms. GER:DB-Math, WIM

3 units, Spr (Brumfiel, G)

MATH 111. Computational Commutative Algebra—Introduction to the theory of commutative rings, ideals, and modules. Systems of polynomial equations in several variables from the algorithmic viewpoint. Groebner bases, Buchberger's algorithm, elimination theory. Applications to algebraic geometry and to geometric problems. GER:DB-Math

3 units, Win (Galatius, S)

MATH 113. Linear Algebra and Matrix Theory—Algebraic properties of matrices and their interpretation in geometric terms. The relationship between the algebraic and geometric points of view and matters fundamental to the study and solution of linear equations. Topics: linear equations, vector spaces, linear dependence, bases and coordinate systems; linear transformations and matrices; similarity; eigenvectors and eigenvalues; diagonalization. GER:DB-Math

3 units, Aut (Vasy, A), Win (Cohen, R)

MATH 114. Linear Algebra and Matrix Theory II—Advanced topics in linear algebra such as: invariant subspaces; canonical forms of matrices; minimal polynomials and elementary divisors; vector spaces over arbitrary fields; inner products; Jordan normal forms; Hermitian and unitary matrices; multilinear algebra; and applications. Prerequisite: 51H or 113. GER:DB-Math

3 units, Spr (Katznelson, Y)

MATH 115. Functions of a Real Variable—The development of real analysis in Euclidean space: sequences and series, limits, continuous functions, derivatives, integrals. Basic point set topology. Honors math majors and students who intend to do graduate work in mathematics should take 171. Prerequisite: 51. GER:DB-Math

3 units, Aut (Ornstein, D), Win (Toussaint, A), Sum (Brumfiel, G)

MATH 116. Complex Analysis—Analytic functions, Cauchy integral formula, power series and Laurent series, calculus of residues and applications, conformal mapping, analytic continuation, introduction to Riemann surfaces, Fourier series and integrals. Prerequisites: 52, and 115 or 171. GER:DB-Math

3 units, Win (Li, J)

MATH 120. Modern Algebra—Basic structures in algebra: groups, rings, and fields. Elements of group theory: permutation groups, finite Abelian groups, p-groups, Sylow theorems. Polynomial rings, principal ideal domains, unique factorization domains. GER:DB-Math, WIM

3 units, Aut (Li, J), Spr (Cohen, R)

MATH 121. Modern Algebra II—Continuation of 120. Fields of fractions. Solvable and simple groups. Elements of field theory and Galois theory. Prerequisite: 120. GER:DB-Math

3 units, Win (White, B)

MATH 131. Partial Differential Equations I—First-order equations, classification of second-order equations. Initial-boundary value problems for heat, wave, and related equations. Separation of variables, eigenvalue problems, Fourier series, existence and uniqueness questions. Prerequisite: 53 or equivalent. GER:DB-Math

3 units, Aut, Win (Iyer, G)

MATH 132. Partial Differential Equations II—Laplace's equation and properties of harmonic functions. Green's functions. Distributions and Fourier transforms. Eigenvalue problems and generalized Fourier series. Numerical solutions. Prerequisite: 131. GER:DB-Math

3 units, Spr (Nedelec, L)

MATH 135. Nonlinear Dynamics and Chaos—Topics: one- and two-dimensional flows, bifurcations, phase plane analysis, limit cycles and their bifurcations. Lorenz equations, fractals and strange attractors. Prerequisite: 51 and 53 or equivalent. GER:DB-Math
3 units, Spr (Iyer, G)

MATH 136. Stochastic Processes—(Same as STATS 219.) Introduction to measure theory, Lp spaces and Hilbert spaces. Random variables, expectation, conditional expectation, conditional distribution. Uniform integrability, almost sure and Lp convergence. Stochastic processes: definition, stationarity, sample path continuity. Examples: random walk, Markov chains, Gaussian processes, Poisson processes, Martingales. Construction and basic properties of Brownian motion. Prerequisite: STATS 116 or MATH 151 or equivalent. Recommended: MATH 115 or equivalent. GER:DB-Math
3 units, Aut (Ross, K), Win (Dembo, A)

MATH 138. Celestial Mechanics—Mathematically rigorous introduction to the classical N-body problem: the motion of N particles evolving according to Newton's law. Topics include: the Kepler problem and its symmetries; other central force problems; conservation theorems; variational methods; Hamilton-Jacobi theory; the role of equilibrium points and stability; and symplectic methods. Prerequisites: 53, and 115 or 171. GER:DB-Math
3 units, not given this year

MATH 143. Differential Geometry—Geometry of curves and surfaces in three-space and higher dimensional manifolds. Parallel transport, curvature, and geodesics. Surfaces with constant curvature. Minimal surfaces. GER:DB-Math
3 units, Win (Schoen, R)

MATH 145. Algebraic Geometry—Real algebraic curves, Hilbert's nullstellensatz, complex affine and projective curves, Bezout's theorem, the degree/genus formula, Riemann surfaces, Riemann-Roch theorem. Prerequisites: 106 or 116, and 109 or 120. Recommended: familiarity with surfaces equivalent to 143, 146, 147, or 148. GER:DB-Math
3 units, Spr (Oprea, D)

MATH 146. Analysis on Manifolds—Differentiable manifolds, tangent space, submanifolds, implicit function theorem, differential forms, vector and tensor fields. Frobenius' theorem, DeRham theory. Prerequisite: 52 or 52H. GER:DB-Math
3 units, Win (Wieczorek, W)

MATH 147. Differential Topology—Smooth manifolds, transversality, Sards' theorem, embeddings, degree of a map, Borsuk-Ulam theorem, Hopf degree theorem, Jordan curve theorem. Prerequisite: 115 or 171. GER:DB-Math
3 units, Spr (Wieczorek, W)

MATH 148. Algebraic Topology—Fundamental group, covering spaces, Euler characteristic, homology, classification of surfaces, knots. Prerequisite: 109 or 120. GER:DB-Math
3 units, alternate years, not given this year

MATH 151. Introduction to Probability Theory—Counting; axioms of probability; conditioning and independence; expectation and variance; discrete and continuous random variables and distributions; joint distributions and dependence; central limit theorem and laws of large numbers. Prerequisite: 52 or consent of instructor. GER:DB-Math
3 units, Win (Liu, T)

MATH 152. Elementary Theory of Numbers—Euclid's algorithm, fundamental theorems on divisibility; prime numbers, congruence of numbers; theorems of Fermat, Euler, Wilson; congruences of first and higher degrees; Lagrange's theorem and its applications; quadratic residues; introduction to the theory of binary quadratic forms. GER:DB-Math
3 units, not given this year

MATH 154. Introduction to Algebraic Number Theory—Core concepts, including number fields, Dedekind domains, unique factorization of ideals, quadratic reciprocity theorems, and Fermat's last theorem for regular prime exponents. Prerequisites: 120, 121. GER:DB-Math
3 units, not given this year

MATH 155. Topics in Elementary Number Theory—Theory of quadratic forms, including the results of Fermat, Lagrange, Gauss, the recent fifteen theorem, and Dirichlet's class number formula. Topics may include continued fractions and Pell's equation, algebraic and transcendental numbers, quadratic fields, Fermat's theorem in some special cases, and an introduction to elliptic curves. Prerequisites: 152, or familiarity with the Euclidean algorithm, congruences, residue classes and reduced residue classes, primitive roots, and quadratic reciprocity. Recommended: 120, 121.
3 units, Aut (Soundararajan, K)

MATH 156. Group Representations—Group representations and their characters, classification of permutation group representations using partitions and Young tableaux, group actions on sets and the Burnside ring, and spherical space forms. Applications to geometric group actions and to combinatorics. Prerequisites: linear algebra (51 and 53, or 103 or 113) and group theory (109 or 120). GER:DB-Math
3 units, Spr (Milgram, R)

MATH 161. Set Theory—Informal and axiomatic set theory: sets, relations, functions, and set-theoretical operations. The Zermelo-Fraenkel axiom system and the special role of the axiom of choice and its various equivalents. Well-orderings and ordinal numbers; transfinite induction and transfinite recursion. Equinumerosity and cardinal numbers; Cantor's Alephs and cardinal arithmetic. Open problems in set theory. GER:DB-Math
3 units, Win (Feferman, S)

MATH 171. Fundamental Concepts of Analysis—Recommended for Mathematics majors and required of honors Mathematics majors. Similar to 115 but altered content and more theoretical orientation. Properties of Riemann integrals, continuous functions and convergence in metric spaces; compact metric spaces, basic point set topology. Prerequisites: 51 and 52, or 51H and 52H. GER:DB-Math, WIM
3 units, Aut (Schoen, R), Spr (Licata, J)

MATH 174A. Topics in Analysis and Differential Equations with Applications—For students planning graduate work in mathematics or physics, and for honors math majors and other students at ease with rigorous proofs and qualitative discussion. Topics may include: geometric theory of ODE's with applications to dynamics; mathematical foundations of classical mechanics including variational principles, Lagrangian and Hamiltonian formalisms, theory of integrable systems; theorems of existence and uniqueness; Sturm-Liouville theory. Prerequisite: 53H or 171, or consent of instructor. GER:DB-Math
3 units, Win (Katznelson, Y)

MATH 174B. Honors Analysis—Continuation of 174A. Topics may include: introduction to PDEs including transport equations, Laplace, wave, and heat equations; techniques of solution including separation of variables and Green's functions; Fourier series and integrals; introduction to the theory of distributions; mathematical foundations of quantum mechanics. Prerequisite: 174A. GER:DB-Math
3 units, not given this year

MATH 175. Elementary Functional Analysis—Linear operators on Hilbert space. Spectral theory of compact operators; applications to integral equations. Elements of Banach space theory. Prerequisite: 115 or 171. GER:DB-Math
3 units, Spr (Simon, L)

MATH 180. Introduction to Financial Mathematics—Financial derivatives: contracts and options. Hedging and risk management. Arbitrage, interest rate, and discounted value. Geometric random walk and Brownian motion as models of risky assets. Initial boundary value problems for the heat and related partial differential equations. Self-financing replicating portfolio. Black-Scholes pricing of European options. Dividends. Implied volatility. Optimal stopping and American options. Prerequisite: 53. Corequisites: 131, 151 or STATS 116. GER:DB-Math
3 units, Aut (Toussaint, A)

MATH 197. Senior Honors Thesis
1-6 units, Aut, Win, Spr (Staff)

MATH 199. Independent Work—Undergraduates pursue a reading program; topics limited to those not in regular department course offerings. Credit can fulfill the elective requirement for math majors. Approval of Undergraduate Affairs Committee is required to use credit for honors majors area requirement.
1-3 units, Aut, Win, Spr (Staff)

PRIMARILY FOR GRADUATE STUDENTS

MATH 205A. Real Analysis—Basic measure theory and the theory of Lebesgue integration. Prerequisite: 171 or equivalent.
3 units, Aut (White, B)

MATH 205B. Real Analysis—Point set topology, basic functional analysis, Fourier series, and Fourier transform. Prerequisites: 171 and 205A or equivalent.
3 units, Win (Vasy, A)

MATH 205C. Real Analysis—Continuation of 205B.
3 units, Spr (Katznelson, Y)

MATH 210A. Modern Algebra—Groups, rings, and fields; introduction to Galois theory. Prerequisite: 120 or equivalent.
3 units, Aut (Milgram, R)

MATH 210B. Modern Algebra—Galois theory. Ideal theory, introduction to algebraic geometry and algebraic number theory. Prerequisite: 210A.
3 units, Win (Brumfiel, G)

MATH 210C. Modern Algebra—Continuation of 210B. Representations of groups and noncommutative algebras, multilinear algebra.
3 units, Spr (Bump, D)

MATH 215A. Complex Analysis, Geometry, and Topology—Analytic functions, complex integration, Cauchy's theorem, residue theorem, argument principle, conformal mappings, Riemann mapping theorem, Picard's theorem, elliptic functions, analytic continuation and Riemann surfaces.
3 units, Aut (Li, J)

MATH 215B. Complex Analysis, Geometry, and Topology—Topics: fundamental group and covering spaces, homology, cohomology, products, basic homotopy theory, and applications. Prerequisites: 113, 120, and 171, or equivalent; 215A is not a prerequisite for 215B.
3 units, Win (Carlsson, G)

MATH 215C. Complex Analysis, Geometry, and Topology—Differentiable manifolds, transversality, degree of a mapping, vector fields, intersection theory, and Poincare duality. Differential forms and the DeRham theorem. Prerequisite: 215B or equivalent.
3 units, Spr (Galatius, S)

MATH 216A,B,C. Introduction to Algebraic Geometry—Algebraic curves, algebraic varieties, sheaves, cohomology, Riemann-Roch theorem. Classification of algebraic surfaces, moduli spaces, deformation theory and obstruction theory, the notion of schemes. May be repeated for credit.
3 units, **A:** *Aut,* **B:** *Win,* **C:** *Spr (Vakil, R)*

MATH 217A. Differential Geometry—Smooth manifolds and submanifolds, tensors and forms, Lie and exterior derivative, DeRham cohomology, distributions and the Frobenius theorem, vector bundles, connection theory, parallel transport and curvature, affine connections, geodesics and the exponential map, connections on the principal frame bundle. Prerequisite: 173 or equivalent.
3 units, Aut (Schoen, R)

MATH 217B. Differential Geometry—Riemannian manifolds, Levi-Civita connection, Riemann curvature tensor, Riemannian exponential map and geodesic normal coordinates, Jacobi fields, completeness, spaces of constant curvature, bi-invariant metrics on compact Lie groups, symmetric and locally symmetric spaces, equations for Riemannian submanifolds and Riemannian submersions. Prerequisite: 217A.
3 units, Win (Brendle, S)

MATH 220. Partial Differential Equations of Applied Mathematics—(Same as CME 303.) First-order partial differential equations, method of characteristics, weak solutions, conservation laws, hyperbolic equations, separation of variables, Fourier series, Kirchoff's formula, Huygen's principle, and hyperbolic systems. Prerequisite: foundation in multivariable calculus and ordinary differential equations.
3 units, Aut (Nolen, J)

MATH 221. Mathematical Methods of Imaging—Mathematical methods of imaging: array imaging using Kirchhoff migration and beamforming, resolution theory for broad and narrow band array imaging in homogeneous media, topics in high-frequency, variable background imaging with velocity estimation, interferometric imaging methods, the role of noise and inhomogeneities, and variational problems that arise in optimizing the performance of imaging algorithms and the deblurring of images. Prerequisite: 220.
3 units, Spr (Papanicolaou, G)

MATH 222. Computational Methods for Fronts, Interfaces, and Waves—High-order methods for multidimensional systems of conservation laws and Hamilton-Jacobi equations (central schemes, discontinuous Galerkin methods, relaxation methods). Level set methods and fast marching methods. Computation of multi-valued solutions. Multi-scale analysis, including wavelet-based methods. Boundary schemes (perfectly matched layers). Examples from (but not limited to) geometrical optics, transport equations, reaction-diffusion equations, imaging, and signal processing.
3 units, not given this year

MATH 227. Partial Differential Equations and Diffusion Processes—Parabolic and elliptic partial differential equations and their relation to diffusion processes. First order equations and optimal control. Emphasis is on applications to mathematical finance. Prerequisites: MATH 131 and MATH 136/STATS 219, or equivalents.
3 units, Win (Nolen, J)

MATH 232. Topics in Probability: Geometry and Markov Chains—Dirichlet forms; Nash, Sobolev, and log-Sobolev inequalities; and applications to card shuffling and random walk on graphs. May be repeated for credit.
3 units, not given this year

MATH 234. Large Deviations—(Same as STATS 374.) Combinatorial estimates and the method of types. Large deviation probabilities for partial sums and for empirical distributions, Cramer's and Sanov's theorems and their Markov extensions. Applications in statistics, information theory, and statistical mechanics. Prerequisite: MATH 230A or STATS 310.
3 units, not given this year

MATH 235. Ergodic Theory and Combinatorial Applications—Classical ergodic theory, with applications to combinatorics, including proofs of Szemeredi's theorem and of some extensions of it. May be repeated for credit. Prerequisite: 205A.
3 units, Win (Katznelson, Y)

MATH 236. Introduction to Stochastic Differential Equations—Brownian motion, stochastic integrals, and diffusions as solutions of stochastic differential equations. Functionals of diffusions and their connection with partial differential equations. Random walk approximation of diffusions. Prerequisite: 136 or equivalent and differential equations.
3 units, Win (Papanicolaou, G)

MATH 237. Stochastic Equations and Random Media—Topics in stochastic differential equations relevant for the analysis of processes in random environments emphasizing asymptotic methods and estimation methods. Examples from financial mathematics including stochastic volatility models, credit default models, and interest rate models that deal with the whole yield curve. Prerequisite: 236 or equivalent. Recommended: knowledge of financial mathematics.
3 units, Spr (Papanicolaou, G)

MATH 238. Mathematical Finance—(Same as STATS 250.) Stochastic models of financial markets. Forward and futures contracts. European options and equivalent martingale measures. Hedging strategies and management of risk. Term structure models and interest rate derivatives. Optimal stopping and American options. Corequisites: MATH 236 and 227 or equivalent.
3 units, Win (Papanicolaou, G)

MATH 239. Computation and Simulation in Finance—Monte Carlo, finite difference, tree, and transform methods for the numerical solution of partial differential equations in finance. Emphasis is on derivative security pricing. Prerequisite: 238 or equivalent.
3 units, Spr (Toussaint, A)

MATH 240. Topics in Financial Mathematics: Fixed Income Models—Introduction to continuous time models for arbitrage-free pricing of interest rate derivatives. Bonds, yields, and the construction of yield curves. Caps, floors, swaps, swaptions, and bond options. Short rate models. Yield curve models. Forward measures. Forward and futures. LIBOR and swap market models. Prerequisite: MATH 238.
3 units, Spr (Toussaint, A)

MATH 244. Riemann Surfaces—Compact Riemann surfaces and algebraic curves; cohomology of sheaves; Serre duality; Riemann-Roch theorem and application; Jacobians; Abel's theorem. May be repeated for credit.
3 units, Spr (Oprea, D)

MATH 245A. Topics in Algebraic Geometry: Moduli Theory—Intersection theory on the moduli spaces of stable curves, stable maps, and stable vector bundles. May be repeated for credit.
3 units, not given this year

MATH 245B. Topics in Algebraic Geometry: *Dessin d'Enfants*—Grothendieck's theory of *dessin d'enfants,* a study of graphs on surfaces and their connection with the absolute Galois group of the rational numbers. Belyi's theorem, representations of the absolute Galois group as automorphisms of profinite groups, Grothendieck-Teichmuller theory, quadratic differentials, and the combinatorics of moduli spaces of surfaces. May be repeated for credit.
3 units, not given this year

MATH 248. Algebraic Number Theory—Introduction to modular forms and L-functions. May be repeated for credit.
1-3 units, not given this year

MATH 249A. Distribution Questions in Number Theory—Rigorous results and conjectures about the distributions of objects of number theoretic interest such as: the spacings between consecutive prime numbers; the spacings between consecutive zeros of the Riemann zeta-function; the class numbers of imaginary quadratic fields; and the values L-functions. Prerequisites: 205A,B,C, or comparable knowledge of probability and Fourier analysis.
3 units, Aut (Soundararajan, K)

MATH 249B. Topics in Number Theory: Class Field Theory and Central Simple Algebras—Algebraic number theory; the development of class field theory emphasizing the role of central simple algebras. May be repeated for credit.
3 units, Win (Bump, D)

MATH 249C. Topics in Number Theory: Class Field Theory and the Langlands Conjectures
3 units, Spr (Bump, D)

MATH 254. Geometric Methods in the Theory of Ordinary Differential Equations—Topics may include: structural stability and perturbation theory of dynamical systems; hyperbolic theory; first order PDE; normal forms, bifurcation theory; Hamiltonian systems, their geometry and applications. May be repeated for credit.
3 units, not given this year

MATH 256A. Partial Differential Equations—The theory of linear and nonlinear partial differential equations, beginning with linear theory involving use of Fourier transform and Sobolev spaces. Topics: Schauder and L2 estimates for elliptic and parabolic equations; De Giorgi-Nash-Moser theory for elliptic equations; nonlinear equations such as the minimal surface equation, geometric flow problems, and nonlinear hyperbolic equations.
3 units, Aut (Vasy, A)

MATH 256B. Partial Differential Equations—Continuation of 256A.
3 units, Win (Iyer, G)

MATH 257A,B,C. Symplectic Geometry and Topology—Linear symplectic geometry and linear Hamiltonian systems. Symplectic manifolds and their Lagrangian submanifolds, local properties. Symplectic geometry and mechanics. Contact geometry and contact manifolds. Relations between symplectic and contact manifolds. Hamiltonian systems with symmetries. Momentum map and its properties. May be repeated for credit.
3 units, **A:** *not given this year,* **B:** *not given this year,* **C:** *Aut (Ionel, E)*

MATH 258. Topics in Geometric Analysis—May be repeated for credit.
3 units, Win (Mazzeo)

MATH 263A,B. Lie Groups and Lie Algebras—Definitions, examples, properties. Semi-simple Lie algebras, their structure and classification. Cartan decomposition: real Lie algebras. Representation theory: Cartan-Stiefel diagram, weights. Weyl character formula. Orthogonal and symplectic representations. May be repeated for credit. Prerequisite: 210 or equivalent.
3 units, not given this year

MATH 266. Computational Signal Processing and Wavelets—Theoretical and computational aspects of signal processing. Topics: time-frequency transforms; wavelet bases and wavelet packets; linear and nonlinear multiresolution approximations; estimation and restoration of signals; signal compression. May be repeated for credit.
3 units, not given this year

MATH 269A. Gromov-Witten Invariants—Riemann surfaces and their moduli spaces, Deligne-Mumford compactification, line bundles over Riemann surfaces, Riemann-Roch theorem. J-holomorphic curves in symplectic manifolds, gradient trajectories of the action functional. Elliptic boundary value problems for J-holomorphic curves, index formulas, coherent orientation theory, transversality. Gromov compactness theorem for J-holomorphic curves, symplectic topology via theory of holomorphic curves, Floer homology theory. Applications of holomorphic curves to low dimensional topology. Gromov-Witten invariants, quantum cohomology, and associated algebraic structures. Symplectic field theory and its applications.
3 units, Aut (Milanov, T)

MATH 269B. Fredholm Theory in Polyfolds and Symplectic Field Theory I—Fredholm theory in the new class of spaces called polyfolds, with applications to Gromov-Witten theory and more generally to symplectic field theory. May be repeated for credit.
3 units, Win (Hofer, H)

MATH 269C. Fredholm Theory in Polyfolds and Symplectic Field Theory II
3 units, Spr (Hofer, H)

MATH 270. Geometry and Topology of Complex Manifolds—Complex manifolds, Kahler manifolds, curvature, Hodge theory, Lefschetz theorem, Kahler-Einstein equation, Hermitian-Einstein equations, deformation of complex structures. May be repeated for credit.
3 units, Win (Li, J)

MATH 282A. Low Dimensional Topology—The theory of surfaces and 3-manifolds. Curves on surfaces, the classification of diffeomorphisms of surfaces, and Teichmuller space. The mapping class group and the braid group. Knot theory, including knot invariants. Decomposition of 3-manifolds: triangulations, Heegaard splittings, Dehn surgery. Loop theorem, sphere theorem, incompressible surfaces. Geometric structures, particularly hyperbolic structures on surfaces and 3-manifolds.
3 units, not given this year

MATH 282B. Homotopy Theory—Homotopy groups, fibrations, spectral sequences, simplicial methods, Dold-Thom theorem, models for loop spaces, homotopy limits and colimits, stable homotopy theory.
3 units, Win (Carlsson, G)

MATH 282C. Fiber Bundles and Cobordism—Possible topics: principal bundles, vector bundles, classifying spaces. Connections on bundles, curvature. Topology of gauge groups and gauge equivalence classes of connections. Characteristic classes and K-theory, including Bott periodicity, algebraic K-theory, and indices of elliptic operators. Spectral sequences of Atiyah-Hirzebruch, Serre, and Adams. Cobordism theory, Pontryagin-Thom theorem, calculation of unoriented and complex cobordism. May be repeated for credit.
3 units, Spr (Cohen, R)

MATH 283. Topics in Algebraic and Geometric Topology—May be repeated for credit.
3 units, Win (Cohen, R)

MATH 286. Topics in Differential Geometry—May be repeated for credit.
3 units, Win (Schoen, R), Spr (White, B)

MATH 290B. Finite Model Theory—(Same as PHIL 350B.) Classical model theory deals with the relationship between formal languages and their interpretation in finite or infinite structures; its applications to mathematics using first-order languages. The recent development of the model theory of finite structures in connection with complexity classes as measures of computational difficulty; how these classes are defined within certain languages that go beyond first-order logic in expressiveness, such as fragments of higher order or infinitary languages, rather than in terms of models of computation.
3 units, not given this year

MATH 292A. Set Theory—(Same as PHIL 352A.) The basics of axiomatic set theory; the systems of Zermelo-Fraenkel and Bernays-Gödel. Topics: cardinal and ordinal numbers, the cumulative hierarchy and the role of the axiom of choice. Models of set theory, including the constructible sets and models constructed by the method of forcing. Consistency and independence results for the axiom of choice, the continuum hypothesis, and other unsettled mathematical and set-theoretical problems. Prerequisites: PHIL160A,B, and MATH 161, or equivalents.
3 units, Aut (Staff)

MATH 292B. Set Theory—(Same as PHIL 352B.) The basics of axiomatic set theory; the systems of Zermelo-Fraenkel and Bernays-Gödel. Topics: cardinal and ordinal numbers, the cumulative hierarchy and the role of the axiom of choice. Models of set theory, including the constructible sets and models constructed by the method of forcing. Consistency and independence results for the axiom of choice, the continuum hypothesis, and other unsettled mathematical and set-theoretical problems. Prerequisites: PHIL160A,B, and MATH 161, or equivalents.
3 units, Win (Staff)

MATH 293A. Proof Theory—(Same as PHIL 253A/353A.) Gentzen's natural deduction and sequential calculi for first-order propositional and predicate logics. Normalization and cut-elimination procedures. Relationships with computational lambda calculi and automated deduction. Prerequisites: 151, 152, and 161, or equivalents.
3 units, not given this year

MATH 295. Computation and Algorithms in Mathematics—Use of computer and algorithmic techniques in various areas of mathematics. Computational experiments. Topics may include polynomial manipulation, Groebner bases, computational geometry, and randomness. May be repeated for credit.
3 units, not given this year

MATH 299. Mathematics of the Brain—Computational models of neurons and neural networks. Ensembles of membrane proteins as statistical molecular computers; extension of the Hodgkin and Huxley theory. The whole brain as a dynamical symbolic system. Context-sensitive associative memory, working memory, and computational universality. Programmable and learning neurocomputers.
3 units, Spr (Eliashberg, Y)

MATH 355. Graduate Teaching Seminar—Required of and limited to first-year Mathematics graduate students.
1 unit, Win (Simon, L; White, B)

MATH 360. Advanced Reading and Research
1-9 units, Aut, Win, Spr, Sum (Staff)

MATH 361. Research Seminar Participation—Participation in a faculty-led seminar which has no specific course number.
1-3 units, Aut, Win (White, B), Spr (Kerckhoff, S), Sum (Staff)

MATH 380-389. Graduate Seminars—By arrangement. May be repeated for credit.

MATH 380. Seminar in Applied Mathematics
1-3 units, Aut, Win, Spr (Staff)

MATH 381. Seminar in Analysis
1-3 units, Aut, Win, Spr (Staff)

MATH 384. Seminar in Geometry
1-3 units, Aut, Win, Spr (Staff)

MATH 385. Seminar in Topology
1-3 units, Aut, Win, Spr (Staff)

MATH 386. Seminar in Algebra
1-3 units, Aut, Win, Spr (Staff)

MATH 387. Seminar in Number Theory
1-3 units, Aut, Win, Spr (Staff)

MATH 388. Seminar in Probability and Stochastic Processes
1-3 units, Aut, Win, Spr (Staff)

MATH 389. Seminar in Mathematical Biology
1-3 units, Aut, Win, Spr (Staff)

MATH 391. Research Seminar in Logic and the Foundations of Mathematics—(Same as PHIL 391.) Contemporary work. May be repeated a total of three times for credit.
1-3 units, Aut, Win, Spr (Mints, G; Feferman, S)

MATH 395. Classics in Geometry and Topology—Original papers in geometry and in algebraic and geometric topology. May be repeated for credit.
3 units, Win, Spr (Staff)

MATH 396. Graduate Progress—Results and current research of graduate and postdoctoral students. May be repeated for credit.
1 unit, Aut, Win, Spr (Staff)

MATH 397. Physics for Mathematicians—Topics from physics essential for students studying geometry and topology. Topics may include quantum mechanics, quantum field theory, path integral approach and renormalization, statistical mechanics, and string theory. May be repeated for credit.
1 unit, Aut, Win (Staff)

COGNATE COURSES

PHIL 151/252. First-Order Logic
4 units, Win (Pauly, M)

PHIL 152/252. Computability and Logic
4 units, Spr (Pauly, M)

PHIL 162/262. Philosophy of Mathematics
4 units, Spr (Feferman, S)

STATS 116. Theory of Probability
3-5 units, Aut (Donoho, D), Spr (Wong, W), Sum (Staff)

STATS 310A. Theory of Probability
2-4 units, Aut (Dembo, A)

STATS 310B. Theory of Probability
2-4 units, Win (Siegmund, D)

STATS 310C. Theory of Probability
2-4 units, Spr (Lai, T)

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