Department of Mathematics

Chair
• Shmuel Weinberger

Professors
• Laszlo Babai, Computer Science
• Alexander A. Beilinson
• Danny Calegari
• Francesco Calegari
• Kevin D. Corlette
• Jack D. Cowan
• Marianna Csörnyei
• Vladimir Drinfeld
• Todd Dupont, Computer Science
• Matthew Emerton
• Alex Eskin
• Benson Farb
• Robert A. Fefferman
• Victor Ginzburg
• Denis Hirschfeldt
• Kazuya Kato
• Carlos E. Kenig
• Steven Lalley, Statistics
• Gregory Lawler
• J. Peter May
• Andre Neves
• Bao Chau Ngo
• Madhav Vithal Nori
• Alexander Razborov
• Wilhelm Schlag
• L. Ridgway Scott, Computer Science
• Panagiotis Souganidis
• Sidney Webster
• Shmuel Weinberger
• Amie Wilkinson
• Robert Zimmer

Associate Professors
• Roger Lee
• Maryanthe Malliaris
• Luis Silvestre
• Charles Smart

Assistant Professors
• Aaron Brown
• Tsao-Hsien Chen
• Nikita Rozenblyum
• Mircea Voda

Instructors
• Juliette Bavard
• Maxime Bergeron
• George Boxer
The Department of Mathematics (http://www.math.uchicago.edu) provides a comprehensive education in mathematics which takes place in a stimulating environment of intensive research activity. The graduate program includes both pure and applied areas of mathematics. Ten to fifteen graduate courses are offered every quarter. Several seminars take place every afternoon. There is an active visitors program with mathematicians from around the world coming for periods from a few days to a few months. There are four major lecture series each year: the Adrian Albert Lectures in Algebra, the Antoni Zygmund and Alberto Calderón Lectures in Analysis, the Unni Namboodiri Lectures in Topology, and the Charles Amick Lectures in Applied Mathematics. The activities of the department take place in Eckhart and Ryerson Halls. These contiguous buildings are shared with the Departments of Statistics and Computer Science. The Department of Mathematics and the Department of Computer Science have several joint appointments, and they coordinate their activities. The Department of Mathematics also has joint appointments and joint activity with the Department of Physics.

Graduate Degrees in Mathematics

The graduate program of the Department of Mathematics is oriented towards students who intend to earn a Ph.D. in mathematics on the basis of work done in either pure or applied mathematics. The department also offers the degree of Master of Science in mathematics, which is acquired as the student proceeds on to the Ph.D. degree. Students are not admitted with the Master of Science degree as their final objective. In addition, the department offers a separate Master of Science in Financial Mathematics degree program which is taught in the evenings. See the program listing for Financial Mathematics for more information.
The divisional requirements for these degrees can be found in the section on the Division of the Physical Sciences in these Announcements. The departmental requirements for students choosing the program in applied mathematics are described below under the heading, Graduate Degrees in Applied Mathematics. Otherwise, the requirements are as follows.

The Degree of Master of Science

The candidate must pass, to the instructor’s satisfaction, the nine basic first year graduate courses in the areas of

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<tr>
<th>Course</th>
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<th>Credits</th>
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<tr>
<td>MATH 32500</td>
<td>Algebra I</td>
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<td>MATH 32600</td>
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<td>MATH 31200</td>
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<td>MATH 31900</td>
<td>Topology and Geometry III</td>
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With the approval of the department, the exceptionally well prepared student may place out of one or more of these courses, and substitute a more advanced course.

If any of these courses are not passed to the instructor’s satisfaction, the student will be required to take an oral exam in those subject areas before receiving the Master of Science degree.

The Degree of Doctor of Philosophy

For admission to candidacy for the Doctor of Philosophy, an applicant must demonstrate the ability to meet both the divisional requirements and the departmental requirements for admission.

The applicant must satisfy the above mentioned requirements for the degree of Master of Science in mathematics.

The applicant must satisfactorily complete an oral topic presentation. This presentation covers material that is chosen by the student in consultation with members of the department and is studied independently. The topic presentation is normally made by the end of the student’s second year of graduate study.

The applicant must also successfully complete the department’s program of preparatory training in the effective teaching of mathematics in the English language at a level commensurate with the level of instruction at the University of Chicago.

After successful completion of the topic presentations, the student is expected to begin research towards the dissertation under the guidance of a member of the department. The remaining requirements are to:

1. Complete a dissertation containing original, substantial, and publishable mathematical results
2. Present the contents of the dissertation in an open lecture
3. Pass an oral examination based both on the dissertation and the field of mathematics in which it lies

Graduate Degrees in Applied Mathematics

The Department of Mathematics, through the Computational and Applied Mathematics Program (CAMP), offers interdisciplinary programs in applied mathematics leading to S.M. and Ph.D. degrees. These programs overlap with but are different from the program in pure mathematics and allow for variations depending on the direction of applications the student chooses. Students choosing the applied mathematics program will participate in courses and seminars not only with pure mathematics students, but also with students in the sciences who have chosen an applied mathematics emphasis in their own departments.

Expanded activity in applied mathematics is occurring within the Department of Mathematics and in the Division of the Physical Sciences. Moreover, the department recognizes that students enter applied mathematics from diverse backgrounds, and that some otherwise well qualified students may require more than one year to satisfy the requirements described below.

To obtain the degree of Master of Science in mathematics under the auspices of CAMP, the candidate must meet the departmental requirements stated above, with the modification that the nine graduate courses to be passed are not restricted to those listed above. These nine courses must, however, include the analysis sequence:

MATH 31200-31300-31400  Analysis I-II-III
They must also include a second, approved three quarter sequence of mathematics courses. This will normally be a sequence of applied mathematics courses emphasizing differential equations, ordinary and partial, and their numerical treatment. They may, however, consist of the algebra or topology sequence.

A third approved sequence of courses may be chosen from the offerings of the Department of Mathematics or from those of another department. Possible choices of sequences outside the Department of Mathematics are:

Astronomy & Astrophysics
- ASTR 30100: Stars (100 units)
- ASTR 30200: Astrophysics-2 (100 units)
- ASTR 30300: Interstellar Matter (100 units)

Chemistry
- CHEM 36100: Wave Mechanics and Spectroscopy (100 units)
- CHEM 36200: Quantum Mechanics (100 units)
- CHEM 36300: Statistical Thermodynamics (100 units)

Economics
- ECON 30500: Game Theory (100 units)
- ECON 30600: The Economics of Information (100 units)
- ECON 30700: Decision Theory (100 units)

Geophysical Sciences
- GEOS 34100: Fundamentals of Fluid Mechanics (100 units)
- GEOS 34105: Dynamics of Viscous Fluids (100 units)
- GEOS 34220: Climate Foundations (100 units)

Physics
- PHYS 32200: Advanced Electrodynamics I (100 units)
- PHYS 32300: Advanced Electrodynamics II (100 units)

and a third course to be approved.

The requirements for the Ph.D. in applied mathematics are the same as the departmental requirements listed above. Students are expected to consult course schedules published by the university for information regarding courses offered on an infrequent basis.

Mathematics Courses

**MATH 30200-30300. Computability Theory I-II.**
The courses in this sequence are offered in alternate years.

**MATH 30200. Computability Theory I. 100 Units.**
We investigate the computability and relative computability of functions and sets. Topics include mathematical models for computations, basic results such as the recursion theorem, computably enumerable sets, and priority methods.
Instructor(s): D. Hirschfeldt Terms Offered: Spring
Prerequisite(s): Consent of department counselor. MATH 25500 or consent of instructor.
Equivalent Course(s): CMSC 38000

**MATH 30300. Computability Theory II. 100 Units.**
CMSC 38100 treats classification of sets by the degree of information they encode, algebraic structure and degrees of recursively enumerable sets, advanced priority methods, and generalized recursion theory.
Instructor(s): D. Hirschfeldt Terms Offered: Spring
Prerequisite(s): Consent of department counselor. MATH 25500 or consent of instructor.
Equivalent Course(s): CMSC 38100

**MATH 30500. Computability and Complexity Theory. 100 Units.**
Part one of this course consists of models for defining computable functions: primitive recursive functions, (general) recursive functions, and Turing machines; the Church-Turing Thesis; unsolvable problems; diagonalization; and properties of computably enumerable sets. Part two of this course deals with Kolmogorov (resource bounded) complexity: the quantity of information in individual objects. Part three of this course covers functions computable with time and space bounds of the Turing machine; polynomial time computability, the classes P and NP, NP-complete problems, polynomial time hierarchy, and P-space complete problems.
Instructor(s): A. Razborov Terms Offered: Winter
Prerequisite(s): Consent of department counselor and instructor
Note(s): Not offered in 2016-17.
Equivalent Course(s): CMSC 38500
MATH 30900-31000. Model Theory I-II.
MATH 30900 covers completeness and compactness; elimination of quantifiers; omission of types; elementary chains and homogeneous models; two cardinal theorems by Vaught, Chang, and Keisler; categories and functors; inverse systems of compact Hausdorff spaces; and applications of model theory to algebra. In MATH 31000, we study saturated models; categoricity in power; the Cantor-Bendixson and Morley derivatives; the Morley theorem and the Baldwin-Lachlan theorem on categoricity; rank in model theory; uniqueness of prime models and existence of saturated models; indiscernibles; ultraproducts; and differential fields of characteristic zero.

MATH 30900. Model Theory I. 100 Units.
MATH 30900 covers completeness and compactness; elimination of quantifiers; omission of types; elementary chains and homogeneous models; two cardinal theorems by Vaught, Chang, and Keisler; categories and functors; inverse systems of compact Hausdorff spaces; and applications of model theory to algebra.
Prerequisite(s): MATH 25500 or 25800
Note(s): This course is offered in alternate years.

MATH 31000. Model Theory II. 100 Units.
MATH 31000 covers saturated models; categoricity in power; the Cantor-Bendixson and Morley derivatives; the Morley theorem and the Baldwin-Lachlan theorem on categoricity; rank in model theory; uniqueness of prime models and existence of saturated models; indiscernibles; ultraproducts; and differential fields of characteristic zero.
Terms Offered: Spring
Prerequisite(s): MATH 30900
Note(s): This course is offered in alternate years.

MATH 31200-31300-31400. Analysis I-II-III.
Analysis I-II-III

MATH 31200. Analysis I. 100 Units.
Topics include: Measure theory and Lebesgue integration, harmonic functions on the disk and the upper half plane, Hardy spaces, conjugate harmonic functions, Introduction to probability theory, sums of independent variables, weak and strong law of large numbers, central limit theorem, Brownian motion, relation with harmonic functions, conditional expectation, martingales, ergodic theorem, and other aspects of measure theory in dynamics systems, geometric measure theory, Hausdorff measure.
Terms Offered: Autumn
Prerequisite(s): MATH 26200, 27000, 27200, and 27400; and consent of director or co-director of undergraduate studies

MATH 31300. Analysis II. 100 Units.
Topics include: Hilbert spaces, projections, bounded and compact operators, spectral theorem for compact selfadjoint operators, unbounded selfadjoint operators, Cayley transform, Banach spaces, Schauder bases, Hahn-Banach theorem and its geometric meaning, uniform boundedness principle, open mapping theorem, Frechet spaces, applications to elliptic partial differential equations, Fredholm alternative.
Terms Offered: Winter
Prerequisite(s): MATH 31200

MATH 31400. Analysis III. 100 Units.
Topics include: Basic complex analysis, Cauchy theorem in the homological formulation, residues, meromorphic functions, Mittag-Leffler theorem, Gamma and Zeta functions, analytic continuation, monodromy theorem, the concept of a Riemann surface, meromorphic differentials, divisors, Riemann-Roch theorem, compact Riemann surfaces, uniformization theorem, Green functions, hyperbolic surfaces, covering spaces, quotients.
Terms Offered: Spring
Prerequisite(s): MATH 31300

MATH 31700-31800-31900. Topology and Geometry I-II-III.
Topology and Geometry I-II-III

MATH 31700. Topology and Geometry I. 100 Units.
Topics include: Fundamental group, covering space theory and Van Kampen’s theorem (with a discussion of free and amalgamated products of groups), homology theory (singular, simplicial, cellular), cohomology theory, Mayer-Vietoris, cup products, Poincare Duality, Lefschetz fixed-point theorem, some homological algebra (including the Kunneth and universal coefficient theorems), higher homotopy groups, Whitehead’s theorem, exact sequence of a fibration, obstruction theory, Hurewicz isomorphism theorem.
Terms Offered: Autumn
Prerequisite(s): MATH 26200, 27000, 27200, and 27400; and consent of director or co-director of undergraduate studies
MATH 31800. Topology and Geometry II. 100 Units.
Topics include: Definition of manifolds, tangent and cotangent bundles, vector bundles. Inverse and implicit function theorems. Sard's theorem and the Whitney embedding theorem. Degree of maps. Vector fields and flows, transversality, and intersection theory. Frobenius' theorem, differential forms and the associated formalism of pullback, wedge product, integration, etc. Cohomology via differential forms, and the de Rham theorem. Further topics may include: compact Lie groups and their representations, Morse theory, cobordism, and differentiable structures on the sphere.
Terms Offered: Winter
Prerequisite(s): MATH 31700

MATH 31900. Topology and Geometry III. 100 Units.
Topics include: Riemannian metrics, connections and curvature on vector bundles, the Levi-Civita connection, and the multiple interpretations of curvature. Geodesics and the associated variational formalism (formulas for the 1st and 2nd variation of length), the exponential map, completeness, and the influence of curvature on the topological structure of a manifold (positive versus negative curvature). Lie groups. The Chern-Weil description of characteristic classes, the Gauss-Bonnet theorem, and possibly the Hodge Theorem.
Terms Offered: Winter
Prerequisite(s): MATH 31800

MATH 32500-32600-32700. Algebra I-II-III.

MATH 32500. Algebra I. 100 Units.
Topics include: Representation theory of finite groups, including symmetric groups and finite groups of Lie type; group rings; Schur functors; induced representations and Frobenius reciprocity; representation theory of Lie groups and Lie algebras, highest weight theory, Schur-Weyl duality; applications of representation theory in various parts of mathematics.
Terms Offered: Autumn
Prerequisite(s): MATH 25700-25800-25900, and consent of director or co-director of undergraduate studies

MATH 32600. Algebra II. 100 Units.
This course will explain the dictionary between commutative algebra and algebraic geometry. Topics will include the following. Commutative ring theory; Noetherian property; Hilbert Basis Theorem; localization and local rings; etc. Algebraic geometry: affine and projective varieties, ring of regular functions, local rings at points, function fields, dimension theory, curves, higher-dimensional varieties.
Terms Offered: Winter
Prerequisite(s): MATH 32500

MATH 32700. Algebra III. 100 Units.
According to the inclinations of the instructor, this course may cover: algebraic number theory; homological algebra; further topics in algebraic geometry and/or representation theory.
Terms Offered: Spring
Prerequisite(s): MATH 32600

MATH 34100. Geometric Literacy-1. 100 Units.
This ongoing course might be subtitled: "what every good geometer should know". The topics will intersperse more elementary background with topics close to current research, and should be understandable to second year students. The individual modules (2-5 weeks each) might be logically interrelated, but we will try to maintain a "modular structure" so that people who are willing to assume certain results as "black boxes" will be able to follow more advanced modules before formally learning all the prerequisites. This years topics might include: basics of symplectic geometry, harmonic maps in geometry, pseudo-Anosov homeomorphisms and Thurston's compactification of Teichmuller space, algebraic geometry for non-algebraic geometers. Prereq: First year graduate sequence.
Instructor(s): Benson Farb
Terms Offered: Autumn
Prerequisite(s): First year graduate sequence.

MATH 34300. Geometric Literacy-3. 100 Units.
This ongoing course might be subtitled: "what every good geometer should know". The topics will intersperse more elementary background with topics close to current research, and should be understandable to second year students. The individual modules (2-5 weeks each) might be logically interrelated, but we will try to maintain a "modular structure" so that people who are willing to assume certain results as "black boxes" will be able to follow more advanced modules before formally learning all the prerequisites. This years topics might include: basics of symplectic geometry, harmonic maps in geometry, pseudo-Anosov homeomorphisms and Thurston's compactification of Teichmuller space, algebraic geometry for non-algebraic geometers. Prereq: First year graduate sequence.
Instructor(s): Benson Farb
Terms Offered: Spring
Prerequisite(s): First year graduate sequence.

MATH 35506. Topics in Harmonic Analysis. 100 Units.
We will discuss some developments in harmonic analysis, but also cover more basic material.
Instructor(s): Wilhelm Schlag
Terms Offered: Spring
MATH 35600. Topics in Dynamical Systems. 100 Units.
An independent study in topics in dynamical systems.
Instructor(s): Anne Wilkinson Terms Offered: Autumn

MATH 36000. Topology Proseminar. 100 Units.
This informal "proseminar" is devoted to topics in algebraic topology and neighboring fields. Talks are given by graduate students, postdocs, and senior faculty. They range from basic background through current research.
Instructor(s): Staff

MATH 36100. Topology Proseminar. 100 Units.
This informal "proseminar" is devoted to topics in algebraic topology and neighboring fields. Talks are given by graduate students, postdocs, and senior faculty. They range from basic background through current research.
Instructor(s): J. Peter May Terms Offered: Winter

MATH 36200. Topology Proseminar. 100 Units.
The Spring proseminar is a more formal version of the Fall and Winter topology proseminar. It will be taught primarily or completely by May, on topics of interest to the participants.

Best,
Instructor(s): J. Peter May Terms Offered: Spring

MATH 37102. Introduction to Minimal Surfaces and applications. 100 Units.
Minimal surfaces have long been a central tool in geometry. I will present the general theory of existence and regularity for minimal surfaces. I will then focus on applications of the existence of minimal surfaces, namely its connection with positive scalar curvature, the Positive Mass Theorem, and classification of manifolds with positive isotropic curvature.
Instructor(s): Andre Neves Terms Offered: Winter
Prerequisite(s): Elliptic theory of PDE's and Riemannian Geometry

MATH 37106. Topics in Geometric Measure Theory-2. 100 Units.
A measure is a way to assign a size to collections of points. Lebesgue measure is the most important example but, depending upon the application, the 'size' of a set may be measured in many different, very interesting ways. The interplay between measure and geometry can be extremely subtle and has given rise to powerful ideas that are used in energy minimisation problems, the theory of partial differential equations and the study of fractal geometry. This is an advanced course on geometric measure theory and its applications.
Instructor(s): Marianna Csornyei Terms Offered: Spring

MATH 37203. Koszul Duality. 100 Units.
Koszul algebras are a class of graded algebras with especially nice homological properties. Koszul duality is an equivalence of derived categories of graded modules over a pair of Koszul dual algebras. A basic example of such a pair is the Symmetric algebra of a vector space and the exterior algebra of the dual vector space and the exterior algebra of the dual vector space. We will discuss applications of Koszul duality to geometric representation theory and to the topology of hyperplane arrangements.
Instructor(s): Victor Ginzburg Terms Offered: Winter

MATH 37204. Geometric Satake. 100 Units.
Geometric Satake is a basic ingredient in the formulation of the Geometric Langlands Program. Our main goal is to introduce the Satake category of perverse sheaves on the affine Grassmannian and to prove the Satake equivalence theorem that states that the Satake category is equivalent, as a monoidal category, to the category of finite dimensional representations of the Langlands dual group. Time permitting, we will then discuss a derived category refinement of the Satake equivalence.
Instructor(s): Victor Ginzburg Terms Offered: Spring

MATH 37500. Algorithms in Finite Groups. 100 Units.
We consider the asymptotic complexity of some of the basic problems of computational group theory. The course demonstrates the relevance of a mix of mathematical techniques, ranging from combinatorial ideas, the elements of probability theory, and elementary group theory, to the theories of rapidly mixing Markov chains, applications of simply stated consequences of the Classification of Finite Simple Groups (CFSG), and, occasionally, detailed information about finite simple groups. No programming problems are assigned.
Instructor(s): L. Babai Terms Offered: Spring
Prerequisite(s): Consent of department counselor. Linear algebra, finite fields, and a first course in group theory (Jordan-Holder and Sylow theorems) required; prior knowledge of algorithms not required
Note(s): This course is offered in alternate years.
Equivalent Course(s): CMSC 36500

MATH 37609. Topics In PDE. 100 Units.
We will study elliptic partial differential equations including regularity results such as De Giorgi/Nash theory, Krylov-Safonov theory, and nonlinear equations.
Instructor(s): Luis Silvestre Terms Offered: Autumn
Prerequisite(s): Math 31200, 31300, 31400
MATH 37760. Modern Signal Processing. 100 Units.
This course covers contemporary developments from time-frequency transforms and wavelets (1980s) to compressed sensing (2000s), a period during which signal processing significantly evolved and broadened to become the "mathematics of information". Topics: Review of classical sampling theory: Shannon-Nyquist, aliasing, filtering. Time-frequency transforms. Frame theory. Wavelet bases and filterbanks. Sparsity and nonlinear approximation. Algorithms: basis pursuit and matching pursuit. Compressed sensing. Matrix completion. Special topics: curvelets, phase retrieval, superresolution. Students who already have an interest in medical imaging (MRI, CT), or geophysical data processing (seismic, e-m), for instance, are welcome. The course assumes some affinity with undergraduate mathematics. The evaluation will consist of homework problems, and a project of the student's choice. The project can either consist in reproducing results from the literature, or can be research-oriented.
Terms Offered: Autumn
Prerequisite(s): Linear algebra and multivariate calculus
Note(s): Not offered in 2017-18
Equivalent Course(s): STAT 37760

MATH 38100. Geometry, Complexity, and Algorithms. 100 Units.
This course will try to explore these three topics and their interactions. Among the topics likely to be discussed are metric measure geometry (e.g. concentration of measure) and its use designing algorithms, machine learning, manifold learning, the complexity of the construction of isotopies and nullcobordisms, the Blum-Cucker-Smale theory of real computation and estimates for the complexity of root finding and related problems, persistence homology and applications, and other topics that seem like a good idea as the course develops.
Instructor(s): Shmuel Weinberger Terms Offered: Winter
Prerequisite(s): Undergraduate mathematics, the idea of a Turing machine and what an algorithm is, ideally a quarter of each of algebra, algebraic topology, differential topology and complex variables (even at the undergraduate level) and the willingness to work.

MATH 38300. Numerical Solutions to Partial Differential Equations. 100 Units.
This course covers the basic mathematical theory behind numerical solution of partial differential equations. We investigate the convergence properties of finite element, finite difference and other discretization methods for solving partial differential equations, introducing Sobolev spaces and polynomial approximation theory. We emphasize error estimators, adaptivity, and optimal-order solvers for linear systems arising from PDEs. Special topics include PDEs of fluid mechanics, max-norm error estimates, and Banach-space operator-interpolation techniques.
Instructor(s): L. R. Scott Terms Offered: Spring. This course is offered in alternate years.
Prerequisite(s): Consent of department counselor and instructor
Equivalent Course(s): CMSC 38300

MATH 38302. Height functions in Number Theory. 100 Units.
I explain height functions on algebraic varieties over number fields and related subjects.
Instructor(s): Kazuya Kato Terms Offered: Winter

MATH 38305. A Second Course In Number Theory. 100 Units.
The goal of this course will be to introduce some new methods and techniques beyond those covered in Math 32700, and also to give many worked examples on how to use these ideas in practice. Specific topics may include L-functions, applications of class field theory, and Diophantine equations.
Instructor(s): Frank Calegari Terms Offered: Autumn
Prerequisite(s): Math 32700

MATH 38405. Arithmetic Combinatorics. 100 Units.
This course covers a variety of topics in arithmetic combinatorics such as inverse problems, incidence geometry, uniformity, regularity and pseudo-randomness. A special attention will be paid to connections to classical mathematics and theoretical computer science.
Instructor(s): Alexander Razborov Terms Offered: Spring

MATH 38509. Brownian Motion and Stochastic Calculus. 100 Units.
This is a rigorous introduction to the mathematical theory of Brownian motion and the corresponding integration theory (stochastic integration). This is material that all analysis graduate students should learn at some point whether or not they are immediately planning to use probabilistic techniques. It is also a natural course for more advanced math students who want to broaden their mathematical education and to increase their marketability for nonacademic positions. In particular, it is one of the most fundamental mathematical tools used in financial mathematics (although we will not discuss finance in this course). This course differs from the more applied STAT 39000 in that concepts are developed precisely and rigorously.
Terms Offered: Autumn
Prerequisite(s): STAT 38300 or MATH 31200, or permission of the instructor.
Equivalent Course(s): STAT 38500
MATH 38511. Brownian Motion and Stochastic Calculus. 100 Units.
This is a rigorous introduction to the mathematical theory of Brownian motion and the corresponding integration theory (stochastic integration). This is material that all analysis graduate students should learn at some point whether or not they are immediately planning to use probabilistic techniques. It is also a natural course for more advanced math students who want to broaden their mathematical education and to increase their marketability for nonacademic positions. In particular, it is one of the most fundamental mathematical tools used in financial mathematics (although we will not discuss finance in this course). This course differs from the more applied STAT 39000 in that concepts are developed precisely and rigorously. Instructor(s): G. Lawler Terms Offered: Autumn Prerequisite(s): The usual prerequisites are either the first-year graduate mathematical analysis sequence (mainly the material in MATH 31200) or STAT 38100-38300, the first two quarters of the statistics measure-theoretic probability sequence. Equivalent Course(s): STAT 38510

MATH 38704. Quantitative Unique Continuation For Elliptic Equations. 100 Units.
In this course we will discuss classical unique continuation results for second order eigenvalue problems. Such results are of interest in themselves, but also in nonlinear pde problems, in mathematical physics and in nodal geometry. In this connection, we will also discuss the recent breakthrough works of Logunov and Malinikova on the Yau and Nadirashvili conjectures in nodal geometry. Instructor(s): Carlos Kenig Terms Offered: Autumn

MATH 38815. Geometric Complexity. 100 Units.
This course provides a basic introduction to geometric complexity theory, an approach to the P vs. NP and related problems through algebraic geometry and representation theory. No background in algebraic geometry or representation theory will be assumed. Instructor(s): K. Mulmuley Terms Offered: Autumn. This course is offered in alternate years. Prerequisite(s): Consent of department counselor and instructor Note(s): Background in algebraic geometry or representation theory not required Equivalent Course(s): CMSC 38815

MATH 38900. Geometry, Complexity, and Algorithms. 100 Units.
This course will try to explore these three topics and their interactions. Among the topics likely to be discussed are metric measure geometry (e.g. concentration of measure) and its use designing algorithms, machine learning, manifold learning, the complexity of the construction of isotopies and nullcobordisms, the Blum-Cucker-Smale theory of real computation and estimates for the complexity of root finding and related problems, persistence homology and applications, and other topics that seem like a good idea as the course develops. Instructor(s): Shmuel Weinberger Terms Offered: Winter Prerequisite(s): Undergraduate mathematics, the idea of a Turing machine and what an algorithm is, ideally a quarter of each of algebra, algebraic topology, differential topology and complex variables (even at the undergraduate level) and the willingness to work.

MATH 39701. Low-Dimensional Topology. 100 Units.
This course will be an introduction to geometric and topological methods in the study of low-dimensional manifolds, especially in dimension 4. Instructor(s): Danny Calegari Terms Offered: Winter

MATH 41005. Sheaf Theory And Homological Algebra-1. 100 Units.
An introduction to Grothendieck's six functor formalism, aimed at second year students. Instructor(s): Madhav Nori Terms Offered: Autumn

MATH 42900. Mathematical Modeling of Large-Scale Brain Activity 1. 100 Units.
An independant study in mathematical modeling. Instructor(s): Jack Cowan Terms Offered: Autumn

MATH 42901. Mathematical Modeling of Large-Scale Brain Activity 2. 100 Units.
Independent study in Mathematical Modeling of Large-Scale Brain Activity 2. Instructor(s): Jack Cowan Terms Offered: Spring Equivalent Course(s): CPNS 42901

MATH 47000. Geometric Langlands Seminar. 100 Units.
This seminar is devoted not only to the Geometric Langlands theory but also to related subjects (including topics in algebraic geometry, algebra and representation theory). We will try to learn some modern homological algebra (Kontsevich's A-infinity categories) and some "forgotten" parts of D-module theory (e.g. the microlocal approach). Instructor(s): Alexander Beilinson, Vladimir Drinfeld Terms Offered: Autumn

MATH 47100. Geometric Langlands Seminar. 100 Units.
This seminar is devoted not only to the Geometric Langlands theory but also to related subjects (including topics in algebraic geometry, algebra and representation theory). We will try to learn some modern homological algebra (Kontsevich's A-infinity categories) and some "forgotten" parts of D-module theory (e.g. the microlocal approach). Instructor(s): Alexander Beilinson, Vladimir Drinfeld Terms Offered: Winter
MATH 47200. Geometric Langlands Seminar. 100 Units.
This seminar is devoted not only to the Geometric Langlands theory but also to related subjects (including topics in algebraic geometry, algebra and representation theory). We will try to learn some modern homological algebra (Kontsevich's A-infinity categories) and some "forgotten" parts of D-module theory (e.g. the microlocal approach).
Instructor(s): Alexander Beilinson, Vladimir Drinfeld Terms Offered: Spring
Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

- Times was used instead of Trajan.
- Times was used instead of Palatino.

The editor may contact Leepfrog for a draft with the correct fonts in place.