Department of Mathematics

Chair

- Bao Châu Ngô

Professors

- Laszlo Babai, Computer Science and Mathematics
- Guillaume Bal, Statistics and Mathematics
- Alexander A. Beilinson
- Danny Calegari
- Francesco Calegari
- Kevin Corlette
- Marianna Csörnyei
- Vladimir Drinfeld
- Matthew Emerton
- Alex Eskin
- Benson Farb
- Robert A. Fefferman
- Simion Filip
- Victor Ginzburg
- Ewain Gwynne
- Denis Hirschfeldt
- Kazuya Kato
- Carlos E. Kenig
- Gregory Lawler, Mathematics and Statistics
- Maryanthe Malliaris
- J. Peter May
- Andre Neves
- Bao Châu Ngô
- Madhav Vithal Nori
- Alexander Razborov, Mathematics and Computer Science
- Luis Silvestre
- Panagiotis Souganidis
- Sidney Webster
- Shmuel Weinberger
- Amie Wilkinson
- Robert Zimmer

Associate Professors

- Roger Lee
- Akhil Mathew

Assistant Professors

- Daniil Rudenko

Instructors

- Karen Butt
- Aaron Calderon
- Justin Campbell
- Leonardo Coregliano
- Sayan Das
- Haoyang Guo
- Joe Jackson
- Michael Klug

- Min Ju Lee
- Yangyang Li
- Kevin Lin
- Ben Lowe
- Zhilin Luo
- Zhimeng Ouyang
- Minjae Park
- Oron Propp
- Lie Qian
- Chengyang Shao
- Tobias Shin
- Andreas Stavrou
- Donald Stull
- Tina Torkaman
- Zhihan Wang
- Nick Wawrykow
- Jincheng Yang
- Zijian Yao
- Yuzhe Zhu

Senior Instructional Professors

- John Alongi
- John Boller
- Lucas Culler
- Jitka Stehnova
- Sarah Ziesler

Lecturer

Assistant Instructional Professors

- Subhadip Chowdhury
- Charles Cunningham
- Kale Davies
- Nicole Pitcher
- Beniada Shabani
- Stephen Yearwood
- Selma Yildirim
- Seyed Zoalroshd

Emeritus Faculty

- Jonathan Alperin
- Spencer Bloch
- Jack D. Cowan
- Todd Dupont
- George Glauberman
- Robert Kottwitz
- Steven Lalley
- Matam P. Murthy
- Niels Nygaard
- L. Ridgway Scott, Computer Science and Mathematics
- Robert I. Soare, Computer Science and Mathematics

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. The Departments of Mathematics, Computer Science and Statistics have several joint appointments, and they coordinate their activities.

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 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 (http://collegecatalog.uchicago.edu/graduate/departmentofmathematics/financialmathematics/) for more information.

The divisional requirements for these degrees can be found in the section on the Physical Sciences Division in these *Announcements.* Otherwise, the requirements are as follows.

The Degree of Master of Science

The candidate must pass, the nine basic first year graduate courses in the areas of

Algebra		
MATH 32500	Algebra I	100
MATH 32600	Algebra II	100
MATH 32700	Algebra III	100
Analysis		
MATH 31200	Analysis I	100
MATH 31300	Analysis II	100
MATH 31400	Analysis III	100
Topology		
MATH 31700	Topology and Geometry I	100
MATH 31800	Topology and Geometry II	100
MATH 31900	Topology and Geometry III	100

At the beginning of each quarter a placement exam is offered for each of the courses above. Students who pass the exam can place out of the course, but must take another course in a related area.

Grading Policy:

A passing grade for graduate student's in Math 59900: Reading/Research Mathematics courses is the grade of "P".

The grading policy for first year graduate courses in mathematics.
P = Satisfactory progress.
C = Student's performance raised some concerns but these can be resolved by asking the student to do some additional work.
D = Student should retake course.

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 pass at least six of the core courses required for the Master in Science in Mathematics, either by taking and passing the course or by passing a placement exam. The applicant must pass at least one core course from each of the three sequences in Algebra, Analysis, and Geometry and Topology.

The applicant must satisfactorily complete a topic exam. This exam 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, and includes both a written proposal and an oral presentation and exam.

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

A joint Ph.D. in Mathematics and Computer Science is also offered. To be admitted to the joint program, students must be admitted by both departments as follows. Each student in this program will have a primary program (either Math or CS). Students apply to their primary program. Once admitted, they can apply to the secondary program for admission to the joint program. This secondary application can occur either before they enter the program or any time during their first four years in their primary program. Simultaneous applications to both programs will also be considered (one of the programs being designated as primary).

Students enrolling in this program need to satisfy the course requirements of both departments. They have to satisfy the course requirements of their primary program on the schedule of that program, and satisfy the course requirements of their secondary program by the end of their fifth year. They also need to satisfy the examination requirements of their primary program, and are expected to write a dissertation in an area relevant to both fields.

Mathematics Courses

MATH 30200-30300-30400. Computability Theory-1; Computability Theory-2; Computability Theory-3.
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 30400. Computability Theory-III. 100 Units.
TBD

MATH 30708. Simple Theories. 100 Units.
Simple theories (so called), introduced almost forty years ago, provide a model theoretic framework for studying certain familes of 'random" objects, such as the theories of random graphs and hypergraphs. Very recent work has shown the class to contain a much greater range of complexity than previously thought. This course will cover the fundamental theorems of simple theories along with some of the new developments.
Instructor(s): Maryanthe Malliaris Terms Offered: Autumn

MATH 30813. Some Logic and Geometry for Mathematicians. 100 Units.
This quarter course will cover three major applications of logic to other branches of mathematics. The first is Tarski's theorem about quantifier elimination and decidability of the first order theory of the reals. This is a cornerstone of real algebraic geometry with major implications in analysis and geometry. The second is the existence of groups with unsolvable word problem and Higman's characterization of finitely generated subgroups of finitely generated groups. This implies that some geometric problems, such as the homeomorphism problem for manifolds, or deciding whether a simplicial complex is a manifold are undecidable (as we hope to explain). And, finally, we will explain why there is no algorithm to decide whether Diophantine equations with integer coefficients have integral solutions, along with some interesting definability questions in this context.
Instructor(s): Shmuel Weinberger, Maryanthe Malliaris Terms Offered: Spring

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 Hausdorf 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.
First graduate course in model theory, covering the basics of the modern field, through stability.
Prerequisite(s): MATH 25500 or 25800
Note(s): This course is offered in alternate years.

MATH 31000. Model Theory II. 100 Units.
Second graduate course in model theory, focusing on the fundamentals of classification theory.
Terms Offered: Spring
Prerequisite(s): MATH 30900
Note(s): This course is offered in alternate years.

MATH 30905. Decidability. 100 Units.
Decision problems in model theoretic algebra, learning and connections to classification theory, and other topics as time permits.
Instructor(s): Maryanthe Malliaris Terms Offered: Winter

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

MATH 31200. Analysis I. 100 Units.
Topics include: Lebesgue integration, Lp spaces and Banach spaces, differentiation theory, Hilbert spaces and Fourier series, Fourier transform, probability spaces and random variables, strong law of large numbers, central limit theorem, conditional expectation and martingales, Brownian motion.
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, mondromy 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.
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 34200. Geometric Literacy-2. 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.

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 34500. Topics in Geometry and Topology. 100 Units.
This course will cover various topics ranging from algebraic and differential geometry to algebraic and geometric topology, often with connections to representation theory and number theory. Recent topics have included Hodge theory, Mostow Rigidity, Topology and geometry of K3 surfaces (joint with Eduard Looijenga), "What all the 3-manifolds are", 4-manifold theory: from Seiberg-Witten to the classification of albebraic surfaces (joint with Danny Calegari), and the cohomology of arithmetic groups (joint with Matt Emerton).
Instructor(s): Benson Farb Terms Offered: Winter
Prerequisite(s): The first year math graduate courses or permission of instructor.

MATH 34600. Topics in Geometry and Topology-2. 100 Units.
This course will cover various topics ranging from algebraic and differential geometry to algebraic and geometric topology, often with connections to representation theory and number theory. Recent topics have included Hodge theory, Mostow Rigidity, Topology and geometry of K3 surfaces (joint with Eduard Looijenga), "What all the 3-manifolds are", 4-manifold theory: from Seiberg-Witten to the classification of albebraic surfaces (joint with Danny Calegari), and the cohomology of arithmetic groups (joint with Matt Emerton).
Instructor(s): Benson Farb Terms Offered: Spring
Prerequisite(s): The first year math graduate courses or permission of instructor.

MATH 35600. Topics in Dynamical Systems. 100 Units.
This course covers selected topics in dynamical systems. Topics vary and may include: ergodic theory, smooth dynamical systems, statistical properties of dynamical systems, and geometry and dynamics.
Instructor(s): Anne Wilkinson Terms Offered: Autumn

MATH 36000. Proseminar: Topology. 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.
Instructor(s): J. Peter May Terms Offered: Spring

MATH 36206. Algebraic Number Theory. 100 Units.
This is a course in basic algebraic number theory. The only prerequisites will be the material covered in the first year algebra graduate sequence.
Instructor(s): Francesco Calegari Terms Offered: Spring

MATH 36507. Condensed Mathematics. 100 Units.
This course is an introduction to the new subject of condensed mathematics introduced by Clausen and Scholze. We will discuss some of the foundational results in the theory and study some of the growing applications to analytic geometry.
Instructor(s): Akhil Mathew and Matthew Emerton Terms Offered: Autumn

MATH 36558. Algebra/Topology. 100 Units.
This will be an advanced course on topics in algebra and topology.
Instructor(s): Akhil Mathew Terms Offered: Spring

MATH 36603. Expander graphs and metric embeddings. 100 Units.
Expander graphs are fundamental objects in pure math and computer science. This course will study examples, constructions and analytic, geometric, and probabilistic properties of these graphs, and later seque to aspects of the theory of metric embeddings of graphs into Euclidean and perhaps other normed spaces
Instructor(s): Shmuel Weinberger Terms Offered: Winter
Prerequisite(s): One year of undergraduate analysis.

MATH 36611. Topics in Analytic Geometry. 100 Units.
This course will cover some recent developments in analytic geometry arising from the new theory of condensed mathematics developed by Clausen and Scholze.
Instructor(s): Akhil Mathew Terms Offered: Autumn
Prerequisite(s): Algebra and Geometry sequences. (1st year), some category theory.

MATH 36704. Dynamics and Applications. 100 Units.
The course will provide an introduction to basic results and techniques in dynamical systems and then discuss selected applications.
Instructor(s): Simion Filip Terms Offered: Winter

MATH 36888. Pseudodifferential Operators with Applications. 100 Units.
In this course I will introduce classical pseudodifferential operators and their calculus and give some applications, including to variable coefficient Schrodinger equations.
Instructor(s): Carlos Kenig Terms Offered: Autumn
Prerequisite(s): The first year graduate sequence in analysis.

MATH 36918. Min-max Methods in Minimal Surfaces. 100 Units.
Min-max methods in minimal surfaces have produced a series of spectacular results lately and settle old questions. I will develop the Algren-Pitts min-max theory from the beginning and explain how that can be used to prove existence of minimal surfaces.
Instructor(s): Andre Neves Terms Offered: Spring

MATH 37001. Bernstein center and cocenter. 100 Units.
We discuss the Bernstein center of a p-adic reductive group, the cocenter of the Hecke algebra as a module over the Bernstein center and its completion. We present Langlands' theory of endoscopy in this language. We discussion the stable Bernstein center, the stable cocenter and their relation to Langlands' functoriality.
Instructor(s): Bao Chau Ngo Terms Offered: Autumn

MATH 37104. Parabolic Equations with Irregular Data and Related Issues. 100 Units.
We present a general theory of existence and uniqueness of linear parabolic equations with Lebesgue/Sobolev regular coefficients and initial conditions. Applications to the theory of stochastic differential equations are also discussed. The course is based on the recent book C. Le Bris/ P.L. Lions, Parabolic Equations with irregular data and related issues. Application to Stochastic Differential Equations, De Gruyter Series in Applied and Numerical Mathematics, Vol. 4, 2019, 165 pages, ISBN 978-3-11-063313-9. For more information on the course: claude.le-bris@enpc.fr

Instructor(s): Claude Le Bris Terms Offered: Winter

MATH 37105. Topics in Geometric Measure Theory I. 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: Autumn

MATH 37111. Quiver Varieties. 100 Units.
Study of quiver varieties.
Instructor(s): Victor Ginzburg Terms Offered: Spring

MATH 37114. 00-categories and their applications in homotopy theory. 100 Units.
In the course we shall cover the basic theory of 00-categories using The Joyal-Lurie approach via Quasi-Categories. We shall then see how the 00-categorical approach sheds light on the homotopy theory of CW-complexes. If time permits we shall then see how to use these methods to study stable homotopy theory. In particular the study of stable homotopy groups of spheres.
Instructor(s): Tomer Schlank Terms Offered: Winter

MATH 37202. Positive Scalar Curvature. 100 Units.
Scalar curvature is the weakest of the curvature notions for Riemannian manifolds. We shall investigate its role, and which manifolds have positive scalar curvature metrics (with complete results in dimensions two and three, conjectures in high dimensions - with some theorems, and great mysteries in dimension four).
Instructor(s): Shmuel Weinberger and Andre Neves Terms Offered: Winter
Prerequisite(s): The first year sequences in geometry and analysis.

MATH 37214. Hecke algebras, Deligne-Lusztig characters, and character sheaves. 100 Units.
We will discuss Hecke algebras, Deligne-Lusztig characters, and character sheaves.
Instructor(s): Victor Ginzburg Terms Offered: Spring

MATH 37219. Crystalline Differential Operators. 100 Units.
Introduction to crystalline differential operators.
Instructor(s): Victor Ginzburg Terms Offered: Winter

MATH 37304. Theory of Elliptic PDES. 100 Units.
We will study the theory for existence and regularity of second order elliptic PDE's. After presenting the basic results (energy estimates, Schauder theory, spectral theory), we will do Di Giorgi-Nash estimates and present several methods to find solutions to quasilinear and fully non-linear second order elliptic PDE's.
Instructor(s): Andre Neves Terms Offered: Winter
Prerequisite(s): Analysis I and II

MATH 37392. Arithmetic Geometry. 100 Units.
I will explain important aspects in arithmetic geometry.
Instructor(s): Kazuya Kato Terms Offered: Winter
Prerequisite(s): Algebra 1-Algebra 3 of the first year graduate courses.

MATH 37410. Topics in low-dimensional topology. 100 Units.
We will discuss topics in low-dimensional topology.
Instructor(s): Danny Calegari Terms Offered: Autumn

MATH 37411. 3-manifolds. 100 Units.
The topic will be foliations, order ability, and the L-space conjecture.
Instructor(s): Danny Calegari Terms Offered: Autumn

MATH 37502. Symplectic Topology and Hamiltonian Dynamics. 100 Units.
Symplectic geometry and topology is a rapidly developing field of mathematics that originated as a geometric tool for addressing problems in classical mechanics. Powerful methods, such as Gromov's theory of holomorphic curves, have led to the discovery of unexpected phenomena related to the geometry and topology of symplectic manifolds and the dynamics of symplectic maps. In this course, after introducing the basic notions of symplectic geometry and topology, we will discuss some of these developments. We will freely use the language of manifolds and differential forms. 1. Linear symplectic geometry. Affine non-squeezing theorem. 2. Symplectic manifolds and Lagrangian submanifolds. Moser stability theorem and homotopy method. 3. Mathematical model of classical mechanics. Hamiltonian dynamics. 4. Group of Hamiltonian difeomorphisms. Hofer's metric. 5. Displacement energy of Lagrangian submanifolds. 6. Holomorphic curves and Lagrangian submanifolds. 7. Rigidity of the Poisson bracket 8. Diameter of the group of Hamiltonian diffeomorphisms. 9. Symplectic fibrations and Hofer's length spectrum. 10. Symplectic, but non-Hamiltonian, diffeomorphisms. Flux. Books: Arnold, V.I., Mathematical methods of classical mechanics. McDuff, D., Salamon, D., Introduction to symplectic topology. Polterovich, L., The geometry of the group of symplectic diffeomorphisms. Polterovich, L., Rosen, D., Function theory on symplectic manifolds.
Instructor(s): Leonid Polterovich Terms Offered: Autumn

MATH 37801. Configuration spaces in topology, algebraic geometry and topological field theory. 100 Units.
Configuration spaces seem ubiquitous nowadays. In this course we discuss their role in various settings in which they occur: topology (involving among other things the little disk operad and a certain spectral sequence), algebraic geometry and associated mixed Hodge structures (the case of algebraic curves being the most interesting case) and their role in the theory of conformal blocks.
Instructor(s): Eduard Looijenga Terms Offered: Autumn

MATH 37902. Topics in unique continuation. 100 Units.
The course will deal with selected topics in unique continuation and boundary unique continuation for elliptic equations, with applications.
Instructor(s): Carlos Kenig Terms Offered: Autumn
Prerequisite(s): First year analysis sequence, undergraduate pde

MATH 37904. Linear and semilinear Schrodinger evolutions, I. 100 Units.
We will develop harmonic analysis tools for the linear Schrodinger evolution that will then be used for the study of semilinear Schrodinger evolutions. In the first quarter we will treat for the semilinear case small data/short time results, while in the second quarter we will study large data for long times, in critical semilinear problems.
Instructor(s): Carlos Kenig Terms Offered: Autumn
Prerequisite(s): The first year graduate analysis sequence and familiarity with the Fourier transform and introductory partial differential equations.

MATH 37905. Linear and semilinear Schrodinger evolutions, II. 100 Units.
In the second quarter we will study large data for long times, in critical semilinear problems.
Instructor(s): Carlos Kenig Terms Offered: Winter
Prerequisite(s): The first year graduate analysis sequence and familiarity with the Fourier transform and introductory partial differential equations.

MATH 37907. Hodge Theory and Moduli. 100 Units.
Perhaps the most important tool for the study of moduli of complex algebraic varieties is the period map, which assigns to a variety its Hodge structure. In this course we shall develop some of the general theory of the notions involved here (including mixed Hodge theory), but examples of interest (some classical and others less so) will be at the center, such as hyperkaehler manifolds---this includes K3 surfaces---and hypersurfaces. This will lead us to see how locally symmetric varieties (such as ball quotients) parametrize Hodge structures. We will also touch on the mixed Hodge theory of the fundamental group and the interesting extensions of Hodge structures that it can give rise to.
Instructor(s): Eduard Looijenga Terms Offered: Autumn
Prerequisite(s): Prerequisites are basic knowledge of manifolds, (co)homology and De Rham theory (as taught in the courses Algebraic Topology and Topology and Geometry II). We shall treat the classical Hodge theorem as a given (but of course state it), which means that we will not get into its proof.

MATH 37908. Topics in Algebraic Geometry-1. 100 Units.
This is in order to develop some basic algebro-geometric literacy. Topics might include moduli spaces, Deligne-Mostow theory, period maps.
Instructor(s): Eduard Looijenga Terms Offered: Autumn
Prerequisite(s): Introductory course in algebraic geometry.

MATH 38002. Representation theory of p-adic groups. 100 Units.
Discussing representation theory of p-adic groups
Instructor(s): Victor Ginzburg Terms Offered: Winter

MATH 38005. Decomposition theorem for perverse sheaves and Hodge theory. 100 Units.
Discussing decomposition theorem for perverse sheaves and Hodge theory
Instructor(s): Victor Ginzburg Terms Offered: Spring

MATH 38010. The Hitchin Morphism. 100 Units.
The Hitchin morphism will be discussed.
Instructor(s): Victor Ginzburg Terms Offered: Winter

MATH 38420. Mathematics of Quantum Computing. 100 Units.
This course is a gentle introduction to mathematical foundations of quantum computing taught in completely rigorous format: we will completely disregard physical aspects and specific questions pertaining to particular implementations. An (approximate) list of topics: reversible, probabilistic and quantum computation. Quantum complexity classes and relations to their classical counterparts. Fundamental quantum algorithms, notably Grover's search and Shor's factoring algorithm. Quantum (query) complexity theory and quantum communication complexity. Quantum probability, super-operators and non-unitary quantum computation. Basics of quantum information theory and quantum error-correction.
Equivalent Course(s): CMSC 38420

MATH 38515. Symplectic Topology. 100 Units.
This is an introduction to symplectic topology. The purpose is to provide background and details for some of the material covered in Leonid Polterovich's course.

Instructor(s): Danny Calegari Terms Offered: Winter

MATH 38595. Topics in Complex Dynamics. 100 Units.
An introduction to the theory of complex dynamics in 1 dimension, especially the theory of rational maps and rational correspondences. Foundations of the theory, quasiconformal analysis, no wandering domains, Mandelbrot set and variations.
Instructor(s): Danny Calegari Terms Offered: Spring

MATH 38599. Introduction to Floer Theories. 100 Units.
An introduction to the use of gauge theoretic methods in 3-manifold topology, including Seiberg-Witten and Heegaard Floer Homology, connections to taut foliations and sutured manifolds. Thurston norm, contact structures, etc.
Instructor(s): Danny Calegari Terms Offered: Winter

MATH 38803. Tamagawa number conjectures for zeta values. 100 Units.
I explain the Tamagawa number conjecture on zeta values, a general conjecture about the arithmetic of various zeta functions.
Instructor(s): Kazuya Kato Terms Offered: Winter

MATH 39013. Crystalline Differential Operators. 100 Units.
Crystalline differential operators will be discussed.
Instructor(s): Victor Ginzburg Terms Offered: Spring

MATH 39902. Topics in Invariant Theory. 100 Units.
We will discuss Topics in Invariant Theory.
Instructor(s): Bao Chau Ngo Terms Offered: Autumn

MATH 42002. P-adic Hodge Theory. 100 Units.
Basic things in p-adic Hodge theory are explained.
Instructor(s): Kazuya Kato Terms Offered: Winter
Prerequisite(s): Algebra 1, 2, 3

MATH 42501. Geometric Representation Theory. 100 Units.
We will discuss Geometric Representation Theory.
Instructor(s): Victor Ginzburg Terms Offered: Winter

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.
The seminar is devoted to the Geometric Langlands theory and related subjects, which covers topics in algebraic geometry, algebra, and representation theory.
Instructor(s): Alexander Beilinson, Vladimir Drinfeld Terms Offered: Winter

MATH 47200. Geometric Langlands Seminar. 100 Units.
The seminar is devoted to the Geometric Langlands theory and related subjects, which covers topics in algebraic geometry, algebra, and representation theory.
Instructor(s): Alexander Beilinson, Vladimir Drinfeld Terms Offered: Spring

MATH 59900. Reading/Research: Mathematics. 300.00 Units.
Readings and Research for working on their PhD

MATH 70000. Advanced Study: Mathematics. 300.00 Units.
Advanced Study: Mathematics